

BBC

GENETIC HUNT FOR NESSIE NEW TECH SOLVING AN ANCIENT MYSTERY

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THE RED PLANET'S SURFACE?



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There's **plastic** in
human poo → p26

WELCOME



The Red Planet is about to get a new resident robot: the Mars InSight lander. InSight doesn't have wheels like Opportunity or Spirit, but when it touches down on Elysium Planitia on 26 November, it will show us a place that's never been explored before: subterranean Mars.

Relatively little is known about what goes on beneath the Red Planet's rocky ranges. But we do know one thing: the planet

rumbles. These Marsquakes send vibrations coursing through the planet's rock and InSight will be there, with some of the most delicate equipment ever launched into space, to listen to what they sound like. In a similar way to how you knock on a wall to tell if it's hollow, the waves, recorded as seismographs along with other data, will paint a picture of what's happening beneath Mars's crust.

Understanding what's going on inside the planet will tell us how it became an irradiated desert, whether or not life could be responsible for all the methane in its atmosphere, and whether Marsquakes might be something a future manned mission to Mars will have to worry about. Turn to p46 to read the whole story.

Before then, it's got to reach the surface in one piece. It'll be one hell of a ride, so make sure you follow @NASAInSight to keep track of the mission and @sciencefocus for more on its findings.

Daniel Bennett

Daniel Bennett, Editor

IN THIS ISSUE



ALEKS KROTOSKI

With the Christmas party season approaching, Aleks looks into the benefits of being alone, and how this differs from social isolation → p31



NICK LYON

Producer Nick describes the challenges of filming the competing packs of painted wolves that feature in BBC One's new natural history series *Dynasties* → p74



DR DARREN NAISH

Palaeontologist Darren meets the geneticist collecting DNA floating in Loch Ness in the hope of answering whether or not a monster lurks there → p66

WHAT WE'VE FOUND OUT THIS MONTH

Elephants can
do **maths** → p28



Triangular
sandwiches
are **tastier**
→ p90



You can squeeze
in **30 Earth-**
sized planets
between here
and **the Moon**
→ p80



The **smell of rain**
is called **petrichor**
→ p89



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CONTENTS

96



REGULARS

6 Eye opener

Mind-blowing images.

10 Reply

Your letters and emails.

15 Discoveries

This month's biggest science news.

PLUS: Missing link between dinosaurs and birds discovered.

31 Aleks Krotoski

Finding happiness in solitude.

32 Michael Mosley

Is it worth giving up booze for a month?

37 Innovations

The latest technology and gadget news.

87 Q&A

Your burning science questions answered.

96 Out there

Books, exhibitions, days out and more.

Contains adult themes that may be unsuitable for younger readers.

102 Crossword

Solve the clues and feel smart.

106 My life scientific

With computer scientist Dr Sue Black.

64 Subscribe today

Save 30 per cent on the *BBC Focus* shop price and get a copy of Stephen Hawking's book.

COVER
STORY



46



FEATURES

Inside Mars

46 What will the InSight mission discover when it digs beneath the surface of the Red Planet?

The nuclear renegades

57 Meet the start-ups that are trying to generate clean energy for everyone via nuclear fusion.

Genetic hunt for Nessie

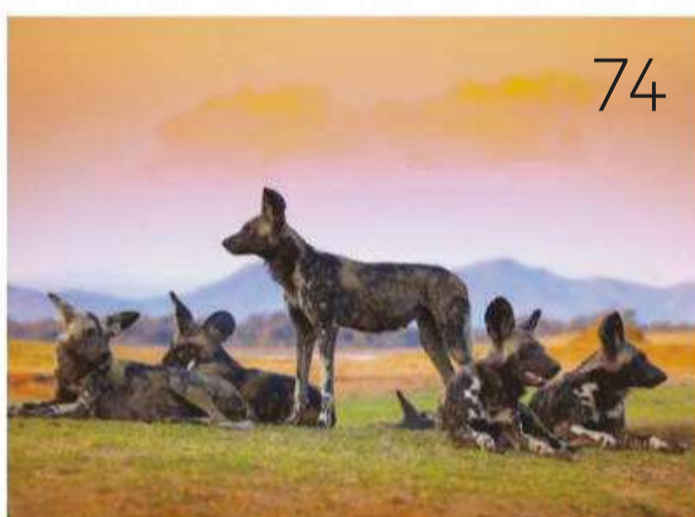
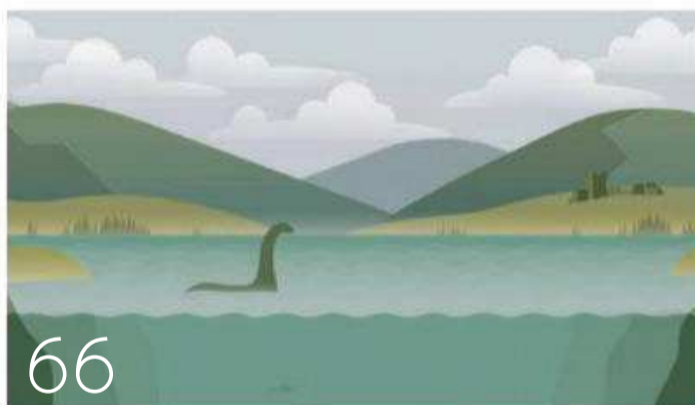
66 Scientists are tracking DNA to solve the mystery of Loch Ness once and for all.

BBC *Dynasties* interview

74 We talk to Nick Lyon, a producer from new BBC series *Dynasties*, about his experiences of filming – and babysitting – painted wolves.

The next space station

78 How NASA and ESA will build a gateway to the Moon, Mars and beyond.



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SPECIAL ISSUE



ON SALE NOW

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In this special edition from the *BBC Focus* team, experts reveal world-changing discoveries, including maths that can stop terrorists, the digital Silk Road and deep-sea mining. buysubscriptions.com/focuscollection



EYE OPENER

Aerosol planet

Our atmosphere is awash with aerosols – microscopic specks of matter including dust, smoke, ash and salt. Humans are responsible for some of these particles, but most come from natural sources, such as volcanoes, dust storms and forest fires.

This NASA visualisation gives a snapshot of Earth's aerosols on 23 August 2018. It was created by a computer model that combines readings taken by satellites and ground sensors, then overlays them on an image of Earth at night.

The oranges are a sooty material called 'black carbon'. The vast swathe across the northwestern US mostly comes from wildfire smoke, while the plume over central Africa is caused by agricultural burning. The purples are dust particles blowing over deserts in Africa and Asia, while the blues are sea salt particles, lofted into the air by sea spray. The two swirls on the far right were created by tropical cyclones Soulik and Cimaron as they neared South Korea and Japan.

NASA/GEOS FP





EYE OPENER

Bread's tangled web

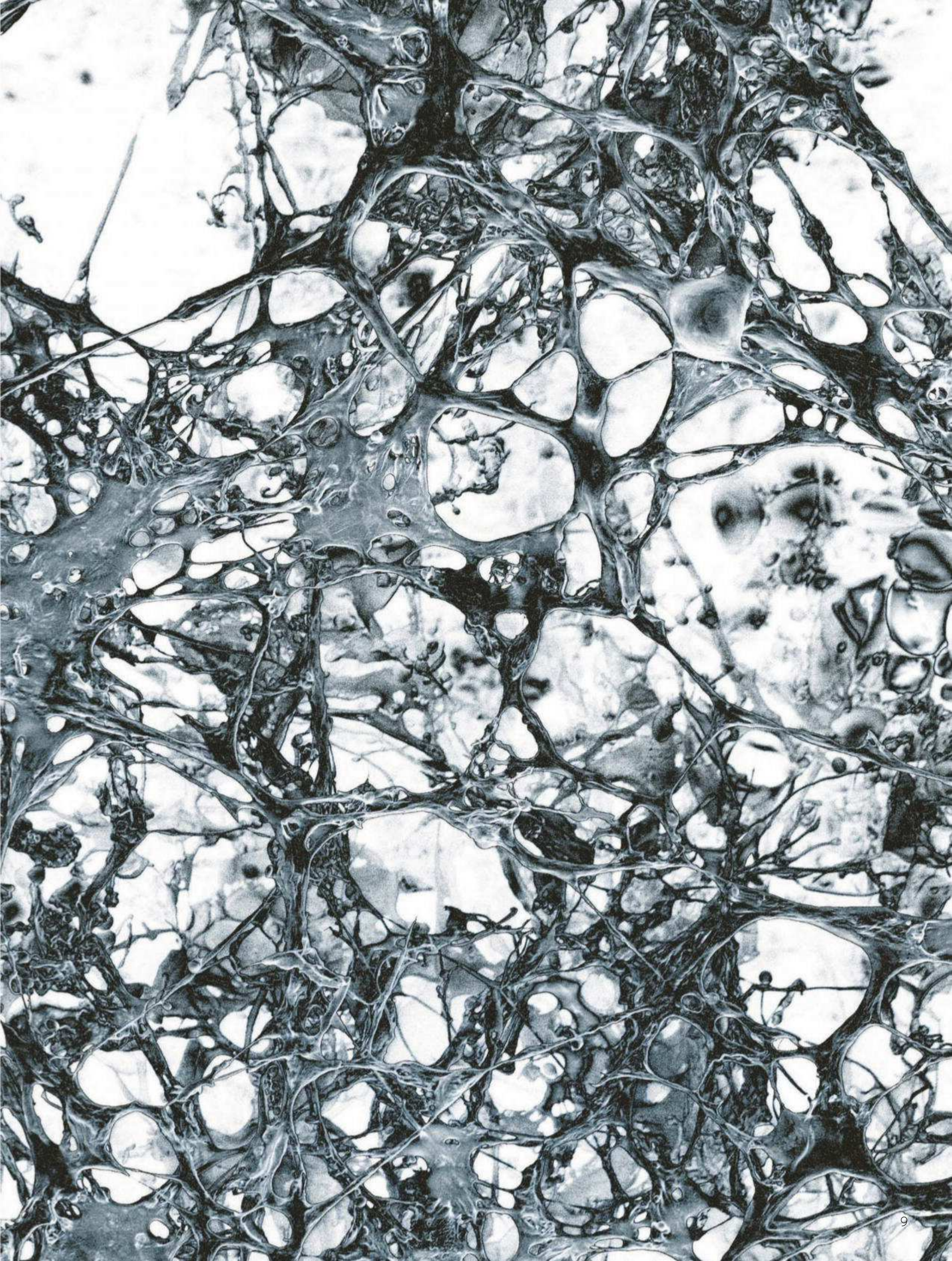
This silvery, web-like structure is a glob of almost pure gluten, the protein that gives bread its bounce. Surprisingly, it's not present in wheat flour, and is only created when you start mixing your ingredients to make bread.

"Even though wheat flour is about one-tenth protein, it has no gluten until it is combined with water and mixed into a dough," says food scientist Dr Stuart Farrimond. "Stirring and kneading causes two smaller proteins, a spaghetti-like glutenin and a meatball-shaped gliadin, to coalesce into long, gluten strands."

As you keep kneading, those gluten strands become longer and stronger. In breads that are leavened with yeast, the gluten network traps carbon dioxide bubbles, which makes the dough rise.

The gluten in this photo was extracted from a dough ball, the starch granules were washed away, and it was magnified 734 times.

NATHAN MYHRVOLD/MODERNIST BREAD



REPLY

Your opinions on science, technology and *BBC Focus*

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MESSAGE OF THE MONTH

Clear as mud

I was excited to read Michael Mosely's column about beating air pollution by bike in the September issue. I cycle to work every day, and worry about the air quality in London, but I find masks uncomfortable and ineffective. My route takes me along mainly back roads, so I was predisposed to like Michael's conclusion that a back streets cycle route is the best way to avoid as much pollution as possible. However, I'm afraid the method of 'experiment' was too problematic, even for me. Michael's test included the following: a walking route on main roads, a cycle route on back roads, and a taxi route on main roads. He then concluded that cycling on back routes was the least polluted journey.

I suppose if those are your only choices, then yes, that would be a fair, if not rigorously scientific, conclusion (factors like the time of day and direction of the journey would preferably have been controlled for). But it was an apples to oranges comparison! What about walking or taking a taxi on back routes? Cycling on main routes? Many cycling superhighways are built along main roads. Given the stakes involved (Michael mentions that 40,000 people are dying early every year in the UK because of pollution), this is an urgent question.

Karen Lawler, London

➔ You make a good point and you are right that my advice was more anecdotal than evidence-based. The people I did the experiment with at King's College have done proper research and, at least for London, produced this interactive map (bit.ly/clean_air_route). I hope you find it useful. – **Dr Michael Mosely, BBC Focus columnist**

WRITE IN AND WIN!

The writer of next issue's *Message Of The Month* wins a **LeakBot**. It is an Internet of Things (IoT) connected smart robot that protects your home against costly water damage. It works around the clock to detect hidden water leaks, and alerts you via an app on your phone before a problem can cause damage to the property. leakbot.io

WORTH
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Where's the best place to ride to avoid air pollution, asks Karen Lawler

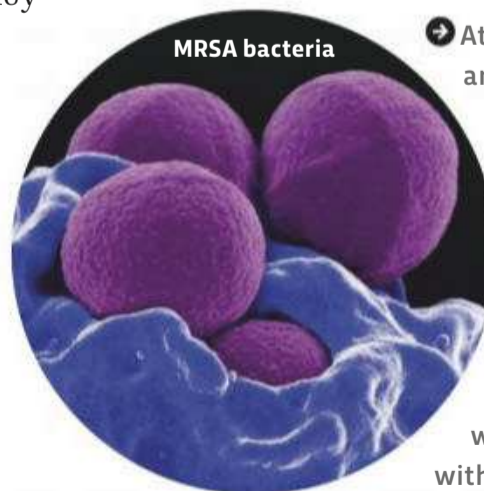
Bugged out

BBC Focus has been my favourite magazine for a long time, I love the mix of articles and the balance of photos to writing. Recently, a few people I know have had infections, two of which were after operations. They needed a load of antibiotics to cure them.

Whenever I hear about these stories, I end up worrying about antibiotic-resistant superbugs. It's probably because I've read too many articles from different magazines about bacterial natural selection, antibiotic resistance

and incurable superbugs. Could we create a 'super antibiotic' that attacks a bacteria in so many ways that bacterial natural selection can't make the jump to resistance, even if you used it a lot?

Brian Bliss, via email



MRSA bacteria

➔ At the moment doctors use antibiotic cocktails to reduce the chance that infectious bacteria become resistant to one drug. Looking further ahead, scientists are investigating medicines that interfere with infectious bacteria without necessarily killing them, circumventing the process of natural selection. For example, in issue 318 (February) we profiled Dr Cassandra

Quave who's working on a treatment that prevents bacteria from talking to each other, and therefore stops them from infecting the host.

– **Daniel Bennett, editor**



Dog-friendly magazines

I enjoyed the article on wolf communication (November), seeing many parallels between them and my own two dogs.

I read with particular interest that only wolves, not dogs, were able to find a treat by looking where a human looked. One of my

LEFT: **Andrew Cirel's dog had a pawsitive (sorry!) response to our feature on wolves**

BELOW: **Music helped Kate Jewel heal from a brain injury**

dogs, who is a working cocker spaniel, is able to respond to me looking in the direction of his training dummy.

Most interestingly, my other dog, a border terrier who is utterly obsessed with nature documentaries on both television and YouTube, jumped onto my knee as I was reading the article on my iPad. I showed him the nine faces of the wolf section, and four times in a row he nosed the 'friendliness' image and was drawn to that facial expression over any other. So I guess you could say that the research has been peer reviewed and approved!

Andrew Cirel, via email

➔ Glad to hear the magazine hasn't gone to the dogs yet. – **Daniel Bennett, editor**

Musician, heal thyself

On your website, your article on the power of music gave me joy [sciencefocus.com/the-human-body/the-power-of-music-for-health/].

Check out *Musicophilia* by Oliver Sacks. I began streaming my own music following a brain injury and it has healed me more than anything else.

Kate Jewel, via email



BBC FOCUS

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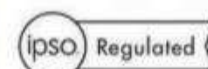
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ANNUAL SUBSCRIPTION RATES (INC P&P):

UK/BFPO £63; Europe & Eire Airmail £66;

Rest of World Airmail £70.



Audit Bureau of Circulations

53,050 (combined; Jan-Dec 2017)



BBC Focus Magazine is published by Immediate Media Company London Limited under licence from BBC Studios who help fund new BBC programmes.

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DISCOVERIES

DISPATCHES FROM THE CUTTING EDGE

DECEMBER 2018

EDITED BY JASON GOODYER

PALAEONTOLOGY

WORLD'S FIRST-EVER SPECIES OF BIRD IDENTIFIED?

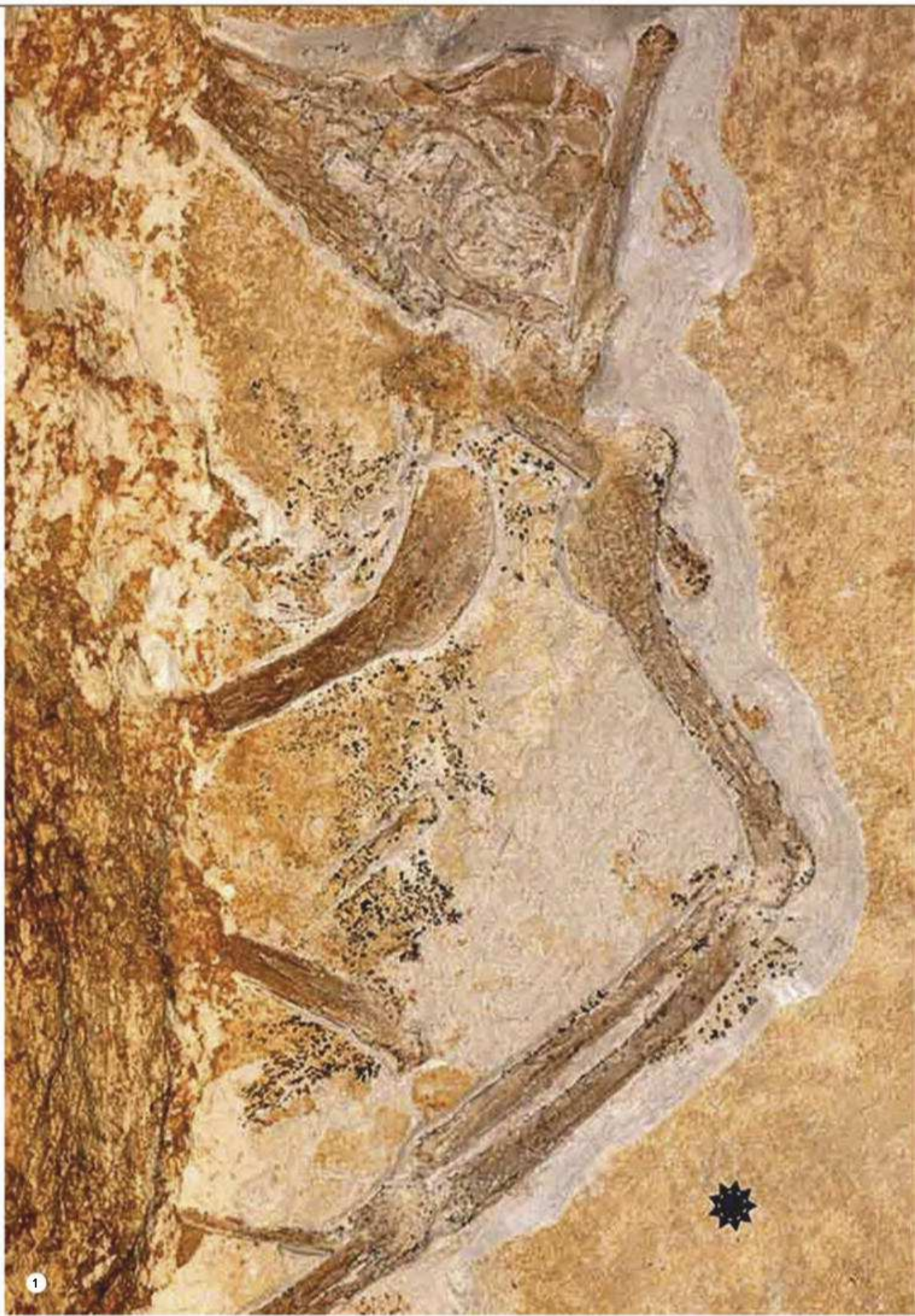
Often referred to as 'the missing link' between dinosaurs and birds, the winged and feathered *Archaeopteryx* now has a newly described relative that's more bird than dinosaur



“IT CONFIRMS *ARCHAEOPTERYX* AS THE FIRST BIRD, AND NOT JUST ONE OF A NUMBER OF THEROPOD DINOSAURS, WHICH SOME AUTHORS HAVE SUGGESTED RECENTLY. YOU COULD SAY IT PUTS *ARCHAEOPTERYX* BACK ON ITS PERCH AS THE FIRST BIRD”

A closer examination of *Archaeopteryx* fossils has led to a new species of the creature being identified. An international team of scientists, led by Dr Martin Kundrát from Slovakia's University of Pavol Jozef Šafárik, have described a type of *Archaeopteryx* that's closer to modern birds in evolutionary terms than any previously analysed.

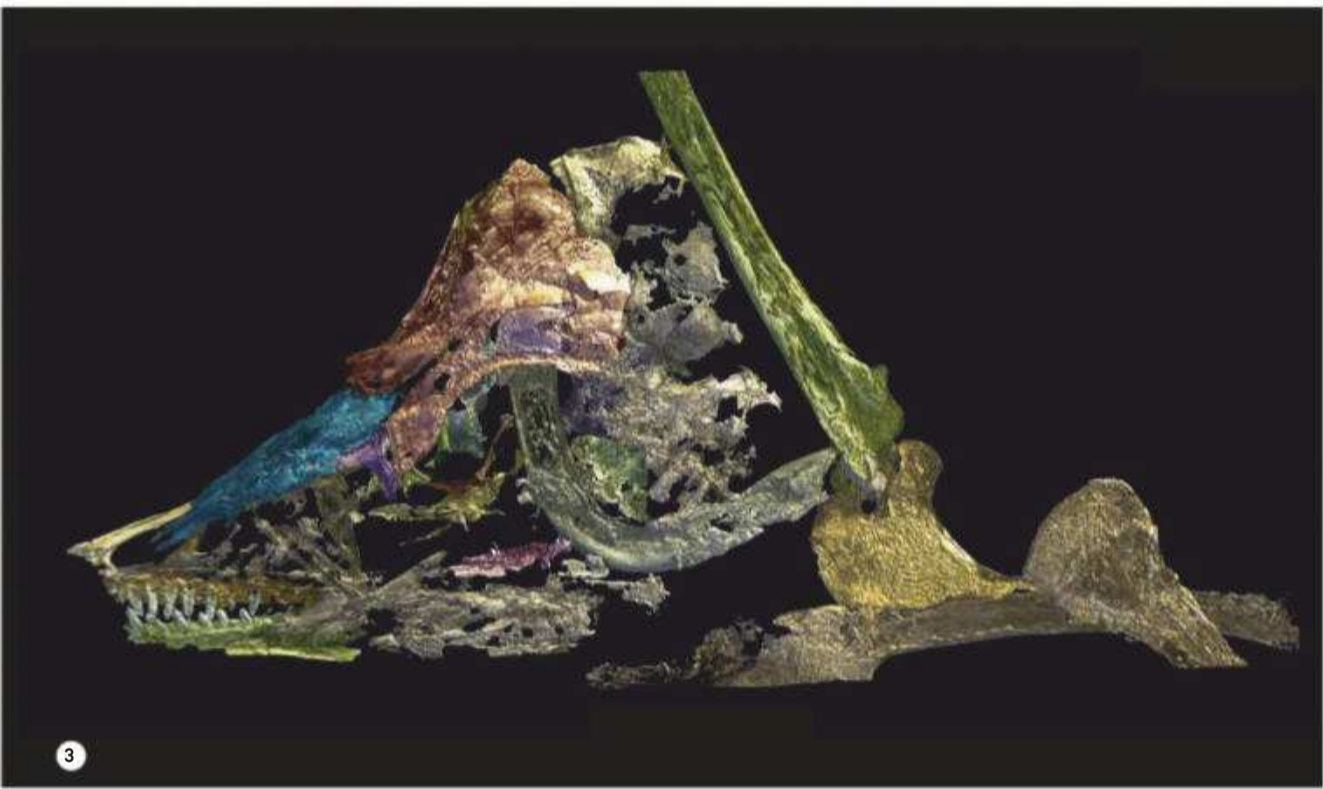
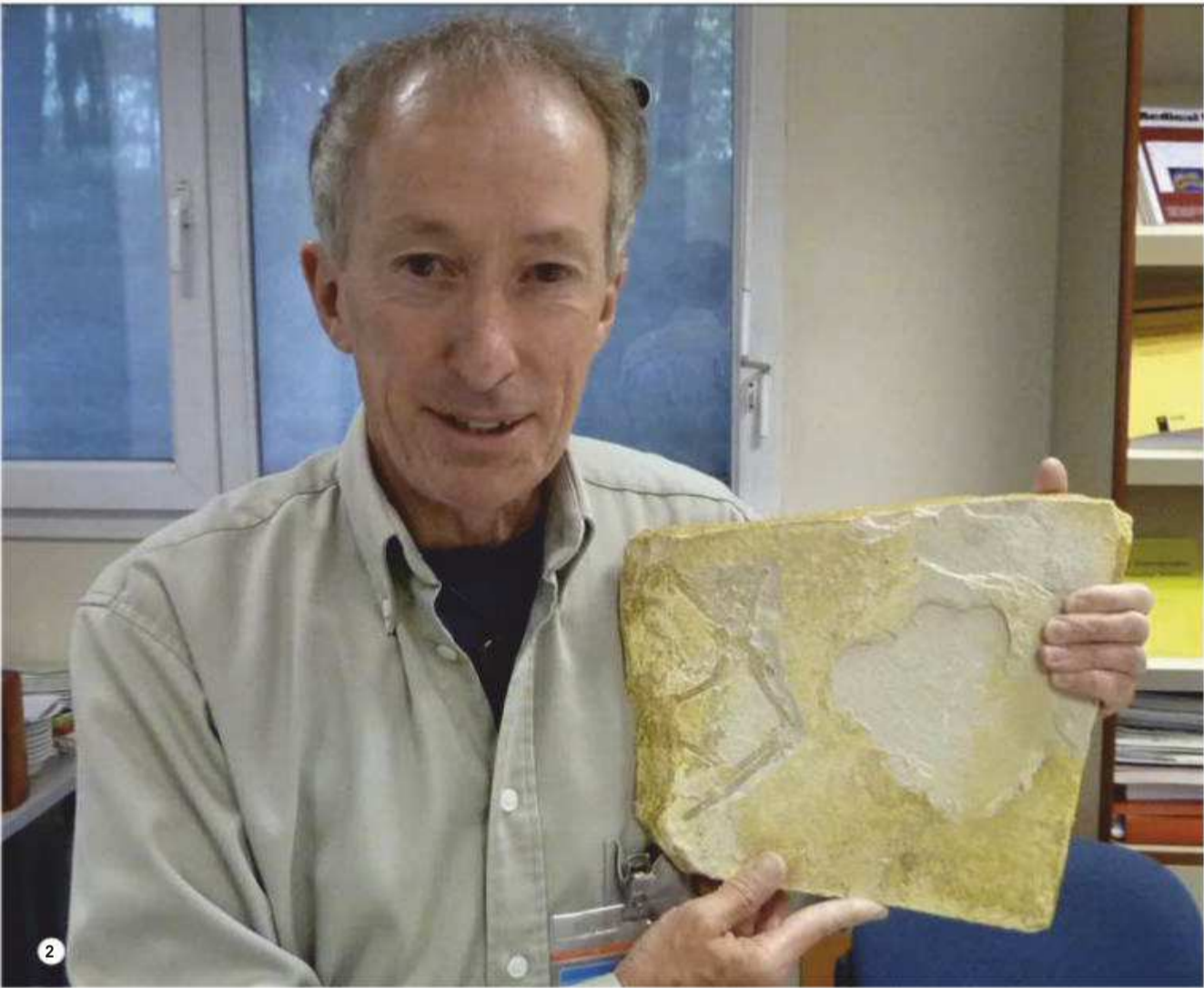
Archaeopteryx, meaning ancient wing, was first named after a solitary feather discovered in southern Germany back in 1861. Since then, only 12 specimens have been found, and they all date back to the late Jurassic period, approximately 150 million years ago. By examining the youngest of all of the known specimens, known as 'specimen number eight', using advanced 3D X-ray scanning techniques, the team found several distinct features about its anatomy that mark it out as being closer to modern birds than



reptiles. This makes it evolutionarily distinctive enough to be described as a whole new species: *Archaeopteryx albersdoerferi*.

“It confirms *Archaeopteryx* as the first bird, and not just one of a number of feathered theropod dinosaurs, which some authors have suggested recently. You could say that it puts *Archaeopteryx* back on its perch as the first bird,” said Dr John Nudds of the University of Manchester and a co-author of the report on the findings.

The team found that *Archaeopteryx albersdoerferi* had fused cranial bones and a complex configuration of reinforced carpals and



EXPERT COMMENT

Dr Darren Naish

Palaeontologist, University of Southampton

Despite being known to science for 160 years, the iconic 'first bird' *Archaeopteryx* remains a popular area of research. For specialists, the significance of Dr Kundrát and his team's study is that it provides quality information on the anatomy of a specimen not studied in detail before. *Archaeopteryx* might be familiar as fossil animals go, but surprisingly little has been published on its anatomy.

It is, however, two other aspects of the study that have captured the most attention. The first is that the specimen is identified as a new species. Until recently, all *Archaeopteryx* specimens were thought to belong to the sole species: *A. lithographica*. But since 2001, experts have agreed that several species are involved. Perhaps this view isn't surprising given that these animals inhabited a tropical archipelago: an environment where the existence of several closely related species would be predicted. The downside to this view is that several specimens are now in limbo. They seem to be part of *Archaeopteryx*, but their precise classification is unresolved and more research is needed.

The team's second main contention is that they have successfully pinned *Archaeopteryx* down on the dinosaur family tree. It is, they say, a member of the bird lineage (termed Avialae), and not part of one of a number of other groups closely related to Avialae, such as the *Velociraptor* or *Troodon* lineages. The possibility that *Archaeopteryx* might not be part of the bird lineage has been promoted in a few studies, and while this it is not an especially popular view, it does seem to be overturned by the new data reported in this study.



1 *Archaeopteryx* specimen number eight. It is younger than other *Archaeopteryx* specimens by around half a million years


2 Co-author of the report Dr John Nudds with specimen number eight

3 3D X-ray image of an *Archaeopteryx* skull

4 An illustration of what *Archaeopteryx* might have looked like

metacarpals (hand bones). The arrangement is similar to those seen in more modern flying birds, but not in the older *Archaeopteryx* species, which more closely resemble reptiles and dinosaurs.

"By digitally dissecting the fossil we found that this specimen differed from all of the others. It possessed skeletal adaptations that would have resulted in much more efficient flight," said Nudds. "In a nutshell we have discovered what *Archaeopteryx lithographica* [other *Archaeopteryx* specimens] evolved into – a more advanced bird, better adapted to flying – and we have described this as a new species of *Archaeopteryx*."



Deviations in exoplanet Kepler-1625b's orbit hint at the presence of what could be the first known exomoon

SPACE

ODD MOVES PROVIDE CLUES TO EXOMOON'S PRESENCE

It's a space oddity for real: astronomers have spotted an exoplanet that wobbles. The wobbling could be due to an exomoon – a moon orbiting a planet outside our Solar System. If confirmed, it would be the first exomoon to be discovered.

Alex Teachey and David Kipping of Columbia University used NASA's Hubble and Kepler space telescopes to gather data on what they think is a huge moon – similar in diameter to Neptune – in orbit around Kepler-1625b, a gas giant exoplanet 8,000 light-years away.

Astronomers search for exoplanets by watching for the temporary dimming of a star's light caused by a planet passing in front of it, referred to as a transit. But while observing Kepler-1625b (discovered in May 2016) they spotted something unusual.

"We saw little deviations and wobbles in the light curve that caught our attention," explained Kipping.

What they noticed was a second, much smaller dip in the star's light after the exoplanet's 19-hour transit, a dip that would be consistent with a following moon.

They also noticed that Kepler-1625b began its transit 1.25 hours earlier than expected because it had wobbled away from its predicted location. Such a wobble could be explained by the presence of another body orbiting a common centre of gravity.

"A companion moon is the simplest and most natural explanation for the second dip in the light curve and the orbit-timing deviation," said Teachey. "It was a shocking moment to see that light curve, my heart started beating a little faster and I just kept looking at that signature. But we knew our job was to keep a level head and test every conceivable way in which the data could be tricking us until we were left with no other explanation."



One of the mice born from two mothers tends to her own offspring

BIOLOGY

DEFECT-FREE MICE BORN FROM SAME-SEX PARENTS

Healthy mice have been born from same-sex parents in China. To investigate the ways that mammalian reproduction differs from other animals, researchers at the Chinese Academy of Sciences used stem cells and genetic manipulation to produce 29 live, healthy offspring from two female mice. The pups have since grown to adulthood and had babies of their own.

The results suggest that the biological barriers to same-sex mammalian reproduction can be circumvented. But the technique isn't foolproof, it seems: pups from two fathers were also born but only survived for around 48 hours.

"The research shows us what's possible," said Wei Li, who took part in the research. "We saw that defects in bimaternal mice can be eliminated and that bipaternal reproduction barriers can also be crossed."

Bimaternal mice (mice with two mums) have been produced prior to this experiment, but were never healthy. To produce the

healthy mice Li and his team had to get around the genomic imprinting barrier, in which certain maternal or paternal genes are imprinted (chemically tagged) and switched off during the initial stages of embryonic development. Since some genes imprinted in a mother's genetic material aren't imprinted in the father's, and vice versa, a mammalian offspring needs material from parents of both sexes in order to get all of the necessary activated genes. In their new research, Li and his team used embryonic haploid stem cells (ESCs) from one female mouse. ESCs only contain half the normal number of chromosomes and DNA. By deleting three imprinting regions of the genome, they were able to make the female stem cells express a more 'male' pattern, then use them to fertilise an egg from another female.

The team hope to explore these techniques further with other research animals, but there are ethical and practical issues to address before it can be considered for humans.

IN NUMBERS

80,000

The age of the Pando aspen – an expanse of 40,000 genetically identical trees deemed to be a single organism found in Fishlake National Forest, Utah. It is among the largest, heaviest and oldest living organisms on Earth.

10 TRILLION

The number of frames captured each second by a camera created by a team based at Caltech and the University of Quebec – that's fast enough to capture the passage of a pulse of light as it travels through space.

300

The number of mammal species thought to have been eradicated due to human activity, as estimated by researchers at Aarhus University in Denmark.

HEALTH

"Short periods of sleep might enhance aspects of memory and thinking"



Daytime naps help the brain process information that's hidden from conscious awareness. Neurologist Dr Liz Coulthard of the University of Bristol explains

How does sleep help us process information?

There's convincing evidence that memories are laid down during deep 'slow-wave' sleep. In your waking hours, when brain cells learn information, it goes into the hippocampus, the memory area of the brain. The memory is still quite fragile and, during sleep, neural networks are activated between the hippocampus and the rest of the brain. Using EEG [electroencephalography], we see cycles of brain waves that are important for strengthening these memories. We're looking into insight – deeper, qualitative information processing – which is more of an emerging field.

How did you test whether naps improve insight?

We developed a task using words associated with an emotion. We presented a word onto a screen for less than 50 milliseconds [one-twentieth of a second] then masked it, so nobody was actually consciously aware of seeing that word. We then presented another 'target' word that could be similar or dissimilar to the masked word: for example, participants might be shown the hidden word 'bad' then see 'unhappy' or 'happy', and we got them to press a button – labelled 'good' or 'bad' – and recorded how quickly they pressed. People

were faster to respond if the word presented before was similar because dissimilar words take more time to process. Next, we gave the participants a period of wake or sleep, and did the same test. The people who stayed awake could watch films or read books, they just had to stay awake. The people who slept got to nap for 90 minutes.

The results showed that the people who napped were much quicker at responding to the target word. This is a fairly small study, with just 16 people and a wide range of ages. We need a bigger group and we'll use EEG to identify the sleep stage which seems to predict performance on the task. We'll also carry out the test overnight. Short periods of sleep might enhance aspects of memory and thinking, but if you have a 15-minute daytime nap, is that better than having 15 minutes extra of night-time sleep?

Why did you study naps?

We wanted to see whether sleep of any type would help people to process information that might enable them to make decisions. But in the day, we experience different hormone levels and light to the night, so this nap design controls those various factors. When we sleep, we go through stages of



sleep, from light to deep and rapid-eye movement sleep – that full cycle lasts about 90 minutes. We got our participants to nap for that amount of time because that would capture most bits of sleep.

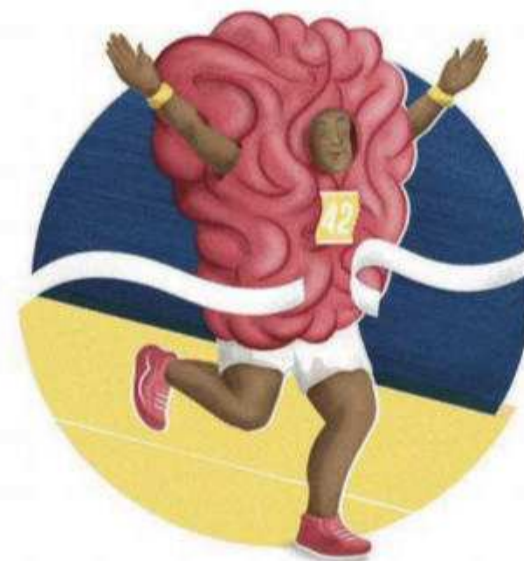
What are the practical applications?

We can look at people who don't sleep well and see all sorts of problems, not just with cognitive and psychological health, but their general health as well. Some of my patients with mild cognitive impairment and dementia have problems with insight and decision-making, and we can see if there's any scope for boosting that by modifying sleep. That can be through really simple things like sleep hygiene, but also more sophisticated brain stimulation using sound or drugs that can promote the deep sleep that might help with processing.



DIGESTED READ

In this small study by Bristol University, researchers found that people were better at processing information after a daytime nap of 90 minutes, compared to people who had stayed awake. Further research could allow the development of sleep modification strategies to help people with cognitive and psychological problems.



RUNNERS

Lace up those trainers! Researchers in France have found that participants who went for a 15-minute jog prior to taking cognitive tests were more mentally sharp than those who'd had 15 minutes' rest. It is thought to be due to increased feelings of vigour.

THE SPANISH

People in Spain are predicted to have the longest life expectancy by 2040, a study at the University of Washington has found. They'll edge ahead of the Japanese, the current record holders, thanks to the benefits of a Mediterranean diet, the scientists say.

GOOD MONTH

BAD MONTH

BLOOD DOPERS

A team at Duke has devised a way to detect 'autologous' blood transfusions, used by some athletes to boost the oxygen-carrying capacity of blood. Duke's method analyses RNA – complex acids involved in carrying genetic data from DNA.

CYBERCHONDRIACS

Internet users are increasingly coming down with cyberchondria, a mental condition in which easy access to information on medical issues causes increased feelings of anxiety over health.



PSYCHOLOGY

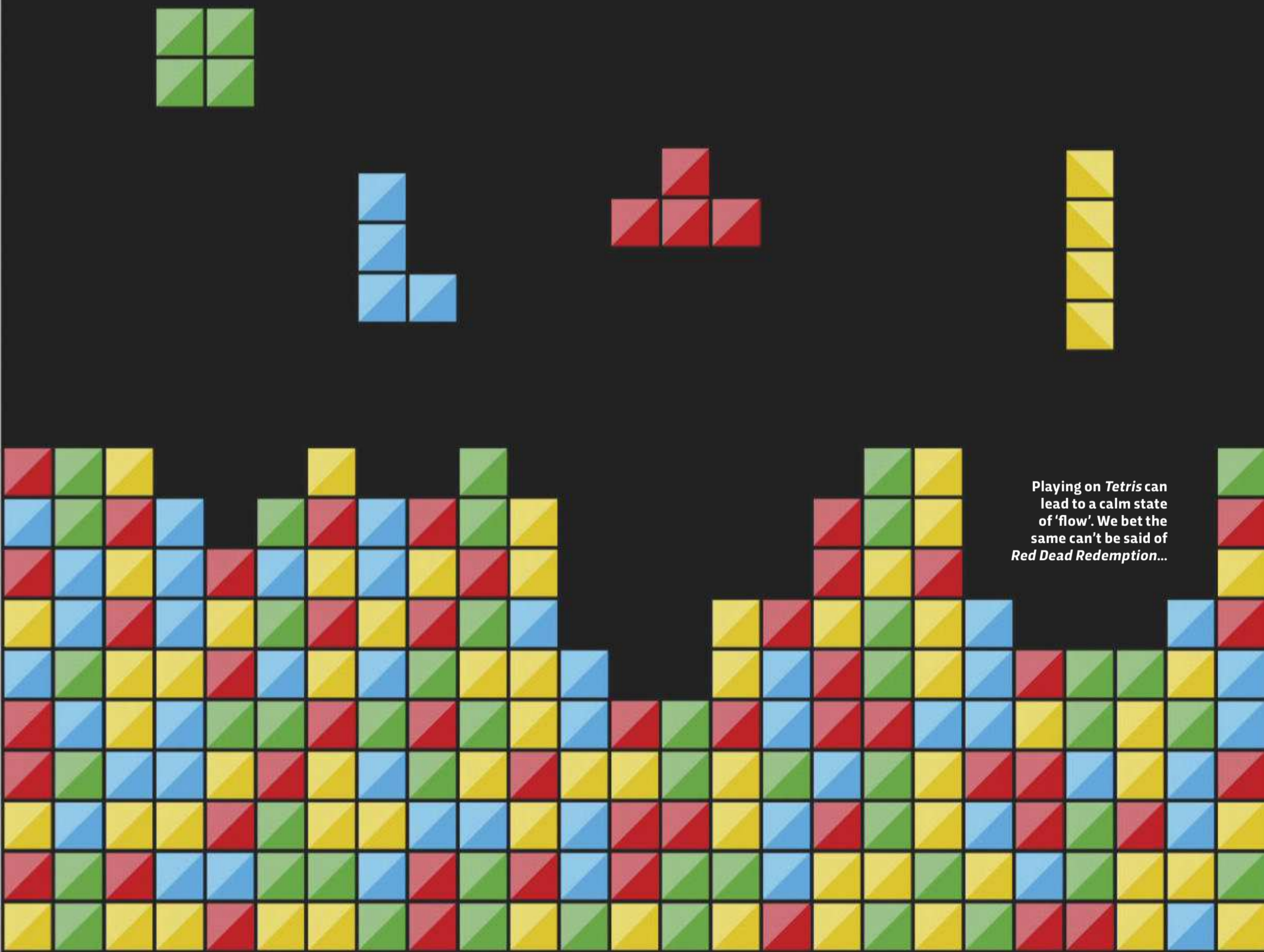
GETTING INTO A ‘FLOW’ STATE WHILE PLAYING *TETRIS* CAN HELP TO COMBAT ANXIETY

Feeling a little worried about an upcoming test, first date or job interview? Why not have a game of *Tetris*? Researchers at the University of California have found that playing *Tetris* – a computer game in which blocks are flipped around and stacked to make complete rows – until a ‘flow’ state is reached can help alleviate negative feelings during periods of anxious waiting.

‘Flow’ is the term that psychologists use to describe a state of mind where you’re so engaged that the rest of the world falls away, and time passes more quickly. It can be achieved by concentrating on a single simple activity. If the activity isn’t challenging enough, you get bored. If it’s too difficult, you get frustrated. “Flow requires a delicate balance,” said Prof Kate Sweeny, who led the research. “It

is most readily achieved with activities that challenge the person somewhat, but not too much; have clear, achievable goals; and that provide the person with feedback about how they’re doing along the way.”

Sweeny had 290 undergraduates fill in a form asking them about their personalities. She then took photos of each of them, telling them that they would be rated on their physical attractiveness. While they were ostensibly being rated, the students were asked to play *Tetris* for 10 minutes. After the game, they completed a survey measuring their sensations of flow, worry and emotion. The participants who said they had achieved flow experienced less negative emotion than other members of the group.



Playing on *Tetris* can lead to a calm state of ‘flow’. We bet the same can’t be said of *Red Dead Redemption*...

PSYCHOLOGY

SMALL DOSES OF PSYCHEDELICS MIGHT HELP YOU SOLVE PROBLEMS

The dose makes the poison, according to the old adage. And a recent study on microdosing with magic mushrooms suggests this might be true.

Research led by Luisa Prochazkova of Leiden University in the Netherlands indicates that ingesting tiny amounts of magic mushrooms could enable people to experience their reputed creativity-boosting effects, without the risk of 'bad trips' associated with higher doses.

Prochazkova and her colleagues set 36 people three tasks before and after giving them a dose of 0.37g of dried mushrooms. The tasks assessed the subjects' convergent thinking (the identification of a single solution to a problem), their fluid intelligence (the capacity to reason and solve new problems) and their divergent thinking (the ability to recognise multiple solutions).

After taking the mushrooms, the participants' convergent thinking improved, they were more flexible in their approaches to finding solutions, and had more ideas about how to complete the divergent thinking task. Their intelligence scores and general analytical abilities didn't change,

There are many types of magic mushrooms, with various toxicities and potencies

however, suggesting that the effect is limited to the creative elements of the brain.

These findings correlate with anecdotal evidence from tech workers in Silicon Valley, where there's a trend developing for microdosing LSD in the belief that it can enhance productivity.

Prochazkova hopes that the findings from her study will stimulate further research into the effects of microdosing psychedelics. "Apart from its benefits as a potential cognitive enhancement technique, microdosing could be further investigated for its therapeutic efficacy to help individuals who suffer from rigid thought patterns or behaviour, such as depression or obsessive-compulsive disorder," she explains.

WARNING

Psilocybin (the psychedelic substance in magic mushrooms) and LSD are Class A drugs according to UK law. Anyone caught in possession of them will face up to seven years in prison, an unlimited fine, or both.

More information and support for those affected by substance abuse problems can be found at bit.ly/drug_support

SPACE

JUPITER'S MOON SHOWS SIGNS OF PAST TECTONIC ACTIVITY



Ganymede, Jupiter's largest moon

Ganymede, Jupiter's largest moon, appears to have previously been through periods of intense tectonic activity, a team at the University of Hawaii has found. Ganymede is believed to consist of vast subterranean oceans covered by an icy shell. A study using imagery collected by the Galileo spacecraft that orbited Jupiter between 1995 and 2003 has found evidence of violent 'strike-slip' tectonics. This causes fault lines that shear against one another horizontally, like the San Andreas fault found in California.

"The unexpected finding was how commonplace strike-slip faulting was. Indicators of strike-slip were observed at all nine sites, representing various geographic locations on Ganymede," said Dr Marissa Cameron, who took part in the research. Though Ganymede is no longer tectonically active, another of Jupiter's moons, Europa, is. Europa is also thought to harbour a subterranean ocean, and is believed to be a likely candidate for finding extraterrestrial microbial life in the Solar System. "Incorporating our observations with previous studies provides an improved representation of Ganymede's tectonic history and allows us to learn more about its neighbour, Europa," said Cameron.

A new orbiter, Europa Clipper, is being developed by NASA and is scheduled to launch sometime between 2022 and 2025. It is planned to make 45 orbits of Europa to further investigate its habitability.

THEY DID WHAT?!

RESEARCHERS
EAVESDROPPED ON
MOUSE ARGUMENTS**What did they do?**

Researchers from the University of Wisconsin-Madison listened in on the coos, chirps and barks between couples of California mice before and after one of them had been taken away to be 'unfaithful' by mating with another mouse. In the wild, California mice that have bonded with a partner stay together for life or until one of them dies.

What did they find?

All of the mice began barking aggressively when first reunited, but some quickly returned to the softer style of communication seen before the separation. Furthermore, the more aggressive couples were less likely to produce offspring, and when they did the males were less attentive to the pups.

Why did they do that?

The team wanted to investigate if the way that the mice communicate reflects how they bond and form relationships.

PALAEOBIOLOGY

**BIRD-LIKE LUNGS HELPED
DINOSAURS RULE THE ROOST**

If you were to step into a time machine and head back to the age of the dinosaurs, you might find it a little hard to catch your breath. Back then, the Earth's atmosphere contained much less oxygen than it does today. So how did dinosaurs manage to lead such active lives? Researchers at Manchester University think they have the answer: dinosaurs had highly efficient bird-like lungs that enabled them to thrive in the harsh conditions.

Crocodylians share a common ancestor with dinosaurs, and birds are dinosaurs' modern-day descendants. It was thought that some dinosaurs would have smooth reptilian-like lungs while others would have more complicated bird-like lungs. To test this, the team used

CT scans to look at the lung cavities of four species of modern crocodylians and 29 bird species, and compared their structure with 16 different dinosaur species.

They found that all of the dinosaurs had bird-like lungs, as well as having vertebrae and skeletal structures that were more similar in shape to birds than reptiles.

"If even the very first dinosaurs to evolve had bird-like lungs, this would go some way to explaining why dinosaurs became the dominant animal species of their time," said Prof Bill Sellers, who took part in the study. "Other animal groups simply may not have had lungs as well suited to extracting oxygen from the air. That simple evolutionary difference may have let dinosaurs rule."



Lungs similar to those of some modern-day birds might have helped dinosaurs breathe the thin air of the prehistoric world

CHINESE ACADEMY OF SCIENCES, GREGORY BERNS/EMORY UNIVERSITY ILLUSTRATION: DAN BRIGHT

Brain scans show man's best friend really does try to understand what you're saying



PSYCHOLOGY

BRAIN SCAN STUDY REVEALS HOW DOGS RESPOND TO LANGUAGE

Who's a clever boy? Many dog owners who talk to their pooches are convinced that their words are being understood. It turns out they may be right. A study at Emory University has found that dogs have a basic understanding of words, are able to distinguish words they have heard before from those they haven't, and are eager to try to understand what is being said to them.

Twelve dogs were trained by their owners to retrieve two objects based on the objects' names – one squishy soft toy and one chewy rubber toy. The dogs were then placed into an fMRI scanner and had their brain activity monitored while their owners said the names of each toy as they held them up. As a control, the owner then spoke gibberish words, such

as 'bobbu' and 'bodmick', then held up novel objects like a hat or a doll.

They found that there was more activation in the auditory regions of the dogs' brains when they reacted to the novel words, suggesting that they sensed that their owners wanted them to understand what they were saying, and were trying to do so.

"We expected to see that dogs neurally discriminate between words that they know and words that they don't," said researcher Ashley Prichard, a PhD candidate in Emory University's department of psychology. "What's surprising is that the result is opposite to that of research on humans – people typically show greater neural activation for known words than novel words."

TRENDING

Your guide to the hottest topics in the world right now

#PLASTICS

PLASTIC POO
Microplastics have been discovered in human poo for the first time. A small study that took stool samples from eight people from different countries found an average of 20 microplastic particles per 10g of stool. This confirms that plastics leached into the food chain eventually make it into human guts.

OCEAN TRASH
The British Antarctic Survey has found that plastic washing up onto the shores of remote South Atlantic islands has increased tenfold over the last decade. More than 90 per cent of the debris the team found was plastic waste. Plastic causes many problems for wildlife including entanglement and starving through ingestion, they say. The arrival of non-indigenous species on floating plastic ‘rafts’ is also a problem.



#CANNABIS

MEDICINAL MOSS
Liverwort, a type of moss, may have similar beneficial effects to cannabis for treating cramps, dizziness and loss of appetite but with a less potent psychoactive effect, according to a study at the University of Bern. The benefits are due to perrottetinene, a substance found in liverwort that is chemically similar to THC – the main psychoactive element of cannabis.



GETTY X3, DAVE BARNES/BAS

#ANTIBIOTICS

HEART PROBLEMS

A study carried out on mice at the University of Wisconsin has found that antibiotics could hinder recovery from a heart attack by depleting the variety of bacteria in the gut microbiome. Antibiotics seem to tamp down the production of chemicals known as short-chain fatty acids, which are produced by the gut's microorganisms and help to regulate the immune system following a heart attack.

SNEAKY DRUGS

A 'Trojan Horse' antibiotic designed by US researchers may help in the fight against antibiotic resistance. The drug, called cefiderocol, binds to iron atoms. This allows it to travel through the defences of certain multidrug-resistant bacteria by 'tricking' their iron transport system into letting it in. So far the drug has treated more than 400 patients with urinary tract or kidney infections.



#DEPRESSION

FAST FOOD BLUES

Junk food may be contributing to depression, a study at James Cook University has found. Researchers compared the incidence of depression in two groups of 100 people on separate islands in the Torres Strait between Papua New Guinea and Australia – one where fast food is readily available and one with no fast food outlets. They found 16 showing signs of moderate to severe depression on the island with fast food outlets and just three on the island with no access to fast food. They say the effect could be down to higher quantities of n-6 PUFA, a fatty acid that's linked to depression and is found in fast food.

HOT BATHS = HAPPINESS?

According to a study from the University of Freiburg, taking a hot bath twice a week may help to relieve the symptoms of depression. During the eight-week trial the study participants were asked to take a twice-weekly 40°C bath for 30 minutes, or do two 45-minute sessions of moderate aerobic exercise such as jogging or cycling. Both groups reported an improvement in mood, but the effect was more marked and kicked in faster in the bathing group. The benefits could come from the effect that hot baths have on resetting our circadian rhythm, which can often be disrupted in those suffering from depression.



SPACE

MARS MAY HAVE ENOUGH OXYGEN TO SUPPORT SUBTERRANEAN LIFE

If there is life on Mars, it seems the best place to look for it may be beneath the surface. According to calculations by a team at NASA's Jet Propulsion Laboratory, the salty water that is thought to exist under the Red Planet's surface could contain enough oxygen to support microbial life.

Recent studies have suggested that liquid water could exist in subsurface pools despite temperatures on the surface being as low as -70°C , as salt present in the water lowers its freezing point. Also, back in 2016, the Curiosity mission discovered that Mars may once have had an oxygen-rich atmosphere, but the loss of the planet's magnetic field led to most of it escaping.

However, according to the team's calculations, this subsurface water could potentially absorb

enough oxygen from the thin Martian atmosphere to sustain basic forms of life at low enough elevations where the atmosphere is thickest. In the best-case scenario, the team found that an unexpectedly high amount of oxygen could exist in the water – much more than the minimum amount needed for aerobic respiration in Earth's oceans.

"Nobody ever thought that the concentrations of dissolved oxygen needed for aerobic respiration could theoretically exist on Mars," said researcher Dr Vlada Stamenković.

The researchers say these findings could inform future missions to Mars by providing better targets to sample and investigate for rovers searching for signs of past or present habitable environments.

It's theoretically possible that microbial life could exist in pools of liquid water present beneath the Martian surface

THINGS WE LEARNT THIS MONTH

CLIMATE CHANGE COULD LEAD TO A GLOBAL BEER SHORTAGE

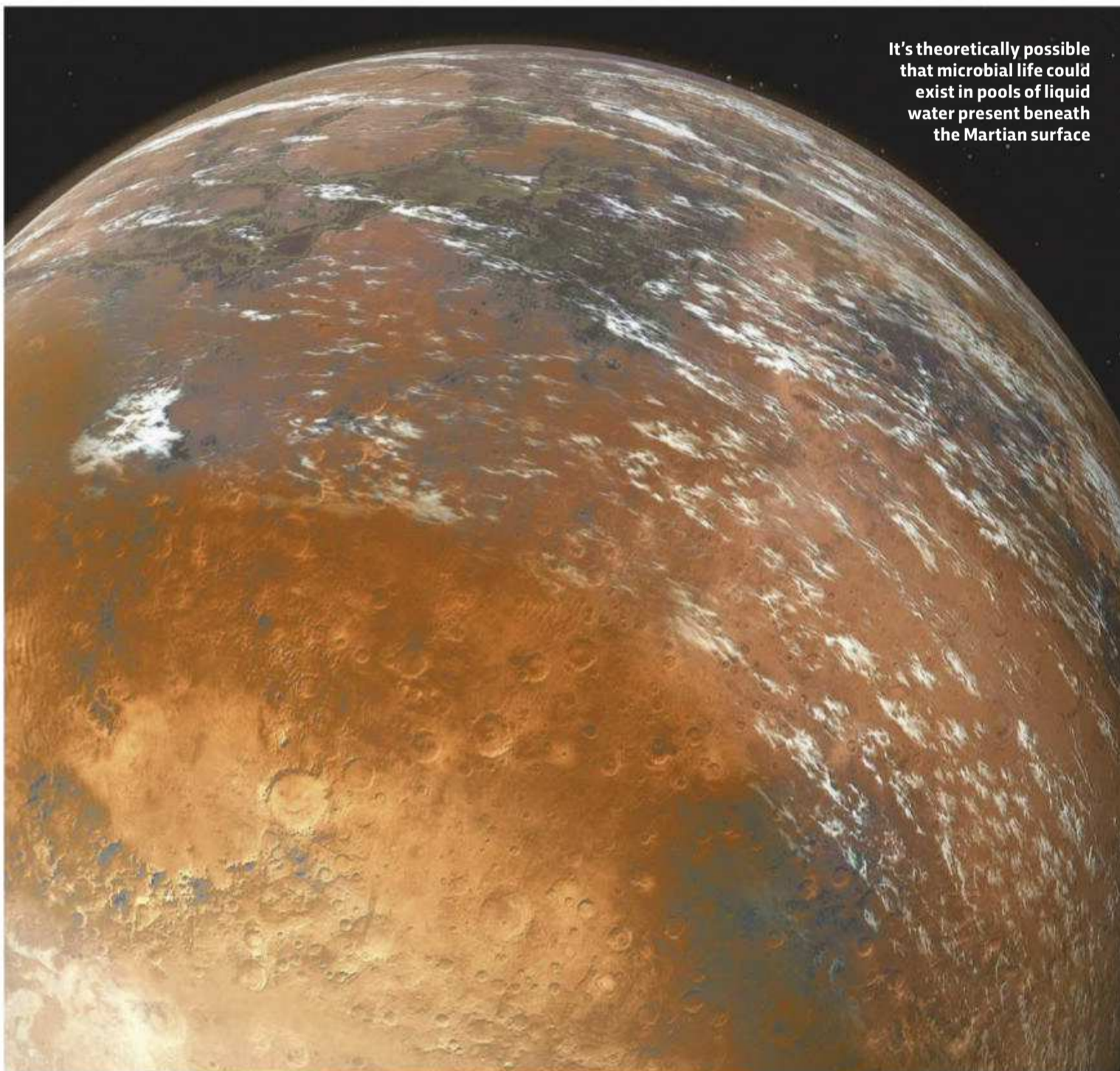
Severe weather including droughts and heatwaves may lead to substantial decreases in barley yields, a study at the University of East Anglia has found. The most extreme scenarios could see beer prices in the UK doubling as a result of the shortages, the researchers say. Better make mine a half.

WEARING WOOL CAN HELP YOU SLEEP

When it comes to nodding off to sleep, wearing wool could be just as effective as counting sheep, a team in Sydney, Australia has found. Study participants wearing wool rather than cotton or polyester fell asleep up to 15 minutes earlier, they say. The benefit is thought to be due to the textile's heat-regulating effects.

ELEPHANTS CAN DO MATHS

Researchers at Japan's Ueno Zoo trained a 14-year-old Asian elephant named Authai to use a touchscreen computer displaying different quantities of fruit and choose the one with the largest number. Authai was able to choose the correct answer almost 70 per cent of the time.



GETTY

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- 15 **BELFAST** SSE Arena
- 16 **DUBLIN** 3 Arena
- 19 **GLASGOW** The SSE Hydro

- 20 **ABERDEEN** AECC
- 21 **LIVERPOOL** Echo Arena
- 22 **NOTTINGHAM** Arena
- 23 **BIRMINGHAM** Arena Birmingham
- 24 **LONDON** The SSE Arena, Wembley
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devolo Magic is available online from mid November. There is a variety of packages to choose from, from Starter Kits and single adapters to Whole-Home-WiFi-Kits for larger homes. devolo provides a three-year manufacturer's warranty for all products.

FEEL THE MAGIC

DEVOLO MAGIC IS THE FUTURE. IT OFFERS MORE SPEED, MORE RANGE AND MORE STABILITY FOR THE FASTEST WI-FI THROUGHOUT THE HOME

Finally! The new season of your favourite series has begun or a long-awaited new game has arrived, and of course you have to give it a go right away. No sooner do you press the key to launch, but your streaming video glitches and the game download sputters and falters. Why? Because the router's Wi-Fi is simply too weak to provide the entire home or flat with fast internet.

THE SOLUTION: DEVOLO MAGIC

For Wi-Fi weakness of this sort, devolo has the perfect solution: devolo Magic uses the building's own electrical circuit to transmit data. The advantage of this powerline technology is that a new Wi-Fi hotspot can be created with devolo Magic at any power socket, ensuring that walls, ceilings and closed doors can no longer block the Wi-Fi signal. An additional benefit is provided by the ethernet ports, where smart TVs, streaming boxes and gaming consoles can be connected by ethernet cable for super-fast speeds.

THE MAGIC BEHIND DEVOLO MAGIC

The new high-end adapters in the devolo Magic series offer speeds of up to 2,400 Mbps. That's enough power for all of today's internet applications, not to mention the multimedia

world of the future: simultaneous streaming of multiple 4K, even 8K videos, data-hungry virtual reality applications and online gaming at maximum speed – devolo Magic can do it all.

MESH-WI-FI INCLUDED

All devolo Magic series Wi-Fi adapters offer top-level Mesh-Wi-Fi. With "Fast Roaming", all mobile devices, such as smartphones and tablets, are always connected to the strongest Wi-Fi hotspot. This is especially important when people move from room to room with their mobile devices. Also, all devolo Magic adapters automatically take on the Wi-Fi settings from the router. This way, the tightly "meshed" Wi-Fi network is created. The result is rocket-fast Wi-Fi, anytime, anywhere!

FULLY AUTOMATED: DEVOLO MAGIC INSTALLS ITSELF

It may sound technical and complicated, but putting it into practice is easy. Once you've plugged in the first adapter, all other adapters that are plugged in within the next two minutes are automatically and securely connected to each other. There is also a new Home Network app available from devolo, which offers a step-by-step installation guide and answers to frequently asked questions.



Without devolo Magic, the router's WiFi is too weak



Ultra-fast internet anywhere with devolo Magic



Just plug it in and finally enjoy Mesh-WiFi, anywhere

FIND MORE INFORMATION AT [DEVOLO.CO.UK](https://www.devolo.co.uk)

devolo

ON THE BENEFITS OF BEING ALONE



BBC
RADIO
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1980W



Aleks Krotoski is a social psychologist, broadcaster and journalist. She presents BBC Radio 4's *Digital Human*.

This is the season to hide in the loo at office Christmas parties. To avoid too much idle chit-chat and loud music. To take a break from the pressure to drink, eat, and be merry. To have a moment in one's own company. To be alone.

I am that person. But I wasn't always. When I was younger, I was the classic extravert, always out, always big and brash, often wearing a silly wig and a loud pattern. I was occupied with a million things, and then once every three weeks I'd cancel my evening plans at the last minute and collapse face-first on my dining room table. Even then, I wasn't really alone. I was asleep. The thing is, I didn't hate being alone, I just wanted to do a lot of things. The world is an exciting place with many opportunities for distraction. Every once in a while, I'd disappear to the far north of Scotland or the Lake District by myself for a fortnight and write and hike and eat a lot of cream teas. But then I'd come back and the party would start again.

A major psychological approach to the modern pursuit of wellbeing is Self Determination Theory. It's become a cornerstone of research since the early 2000s, and is used by theorists and clinicians to try to understand what proportions of work and life, sociability and aloneness we need for optimum mental health. And how well we cope with solitude has become an important consideration.

Feeling okay about being alone has often been associated with introversion – the argument has been that people who don't choose to seek out others prefer their own company. That's an assumption that's been tested by Thuy-vy Nguyen and her colleagues and is currently being peer reviewed. The paper says that enjoying aloneness has more to do with being resistant to peer pressure, and feeling that your behaviour is aligned with your interests, rather than whether you're extraverted or introverted.

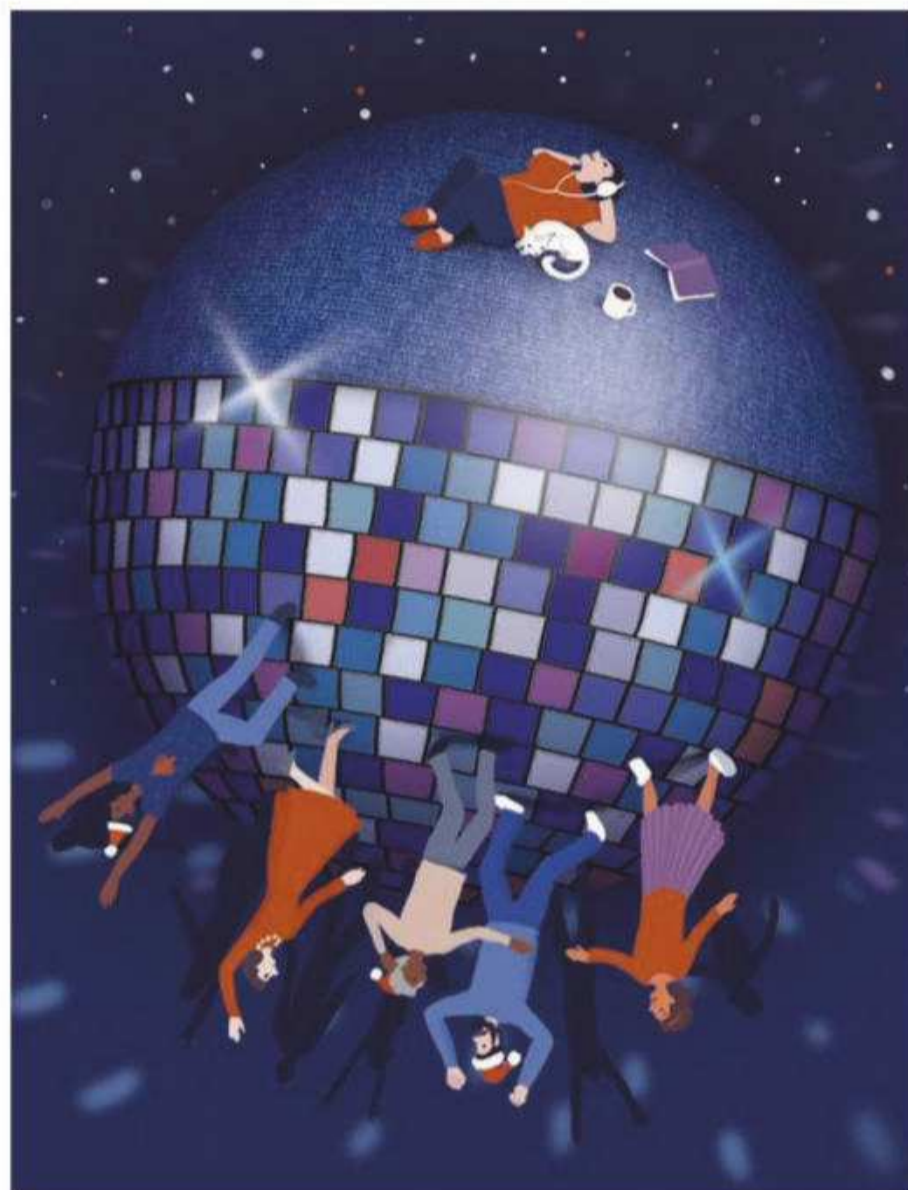
This works only if you can choose it, rather than have it imposed upon you. In a study published in *Gerontology*

in 2016, Theresa Pauly from the University of British Columbia and an international team of psychologists used a combination of biological indicators and psychological assessments to test the difference between being alone out of choice or not. They found that we get more anxious about solitude as we age, but we also increasingly appreciate and enjoy moments of aloneness too. And that makes sense. There's a danger of social isolation as people get older, with the associated negative ramifications for physical and mental health. But choosing to have some silence to collect thoughts and clear the din? Yeah, I'll have some of that.

Now, for people like me who do like to be around others and are happy with my inner voices, I can still experience welcome solitude without booking a silent retreat somewhere else. You don't have to be physically alone to have that respite, according to UCL's Glòria Durà-Vilà and Gerard Leavey. Their 2017 article in *Mental Health, Religion And Culture* reported that contemplative cloistered nuns and monks who live communally avoid interacting with one another in order to achieve a 'perfect closeness with God'. They're not isolated; they're choosing to feel alone out of their own volition.

We might seek to separate ourselves from the frenetic togetherness of a Christmas party. We might seek to be alone together in an always-connected world. But the important thing is to feel that we have chosen our solitude in whatever form it takes, so we can hear ourselves ever more clearly, and ultimately achieve optimum us. **F**

“ENJOYING TIME ALONE IS MORE TO DO WITH BEING RESISTANT TO PEER PRESSURE”



THE TRUTH ABOUT GOING DRY



Michael Mosley is a science writer and broadcaster, who presents *Trust Me, I'm A Doctor* on BBC Two. His latest book is *The Clever Guts Diet* (£8.99, Short Books).

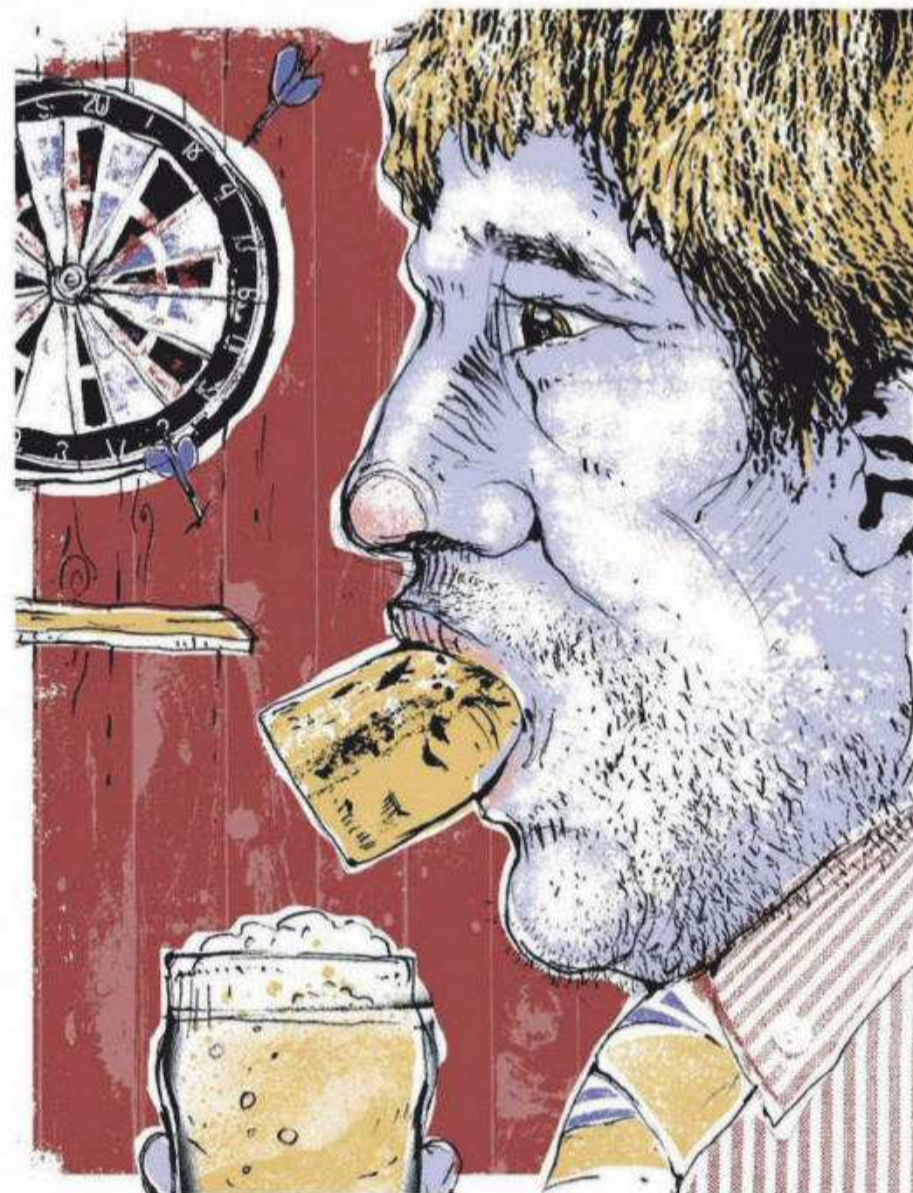
Last month, some people stayed off the booze to Go Sober For October. And after the excesses of the festive period, which is just around the corner, comes the perennial question: should I join in Dry January? There are excellent reasons to drink less if you are currently over the guidelines, which in the UK are 14 units of alcohol a week for men and women. That translates into roughly six glasses of wine, or six pints of beer. A week.

The dangers of going well above these guidelines include increased risk of cancer, obesity and heart disease. Plus, of course, things like crashing your car. As the facts about alcohol become widely available, more and more people are giving it up, permanently. A recent study found that a third of under-25s don't drink at all.

I can see the advantages of total abstinence, but does giving up alcohol for just a few weeks make much of an impact? This time last year I gave it a go for *BBC Focus*, and was generally unimpressed with the results. Over the course of a rather dull month I lost a bit of weight, saved some money, and then took up drinking again as soon as it was over. But how do others react, particularly heavier drinkers than me? A team of scientists led by Prof Rajiv Jalan asked a group of 94 healthy, middle-aged people, who averaged 25 units a week, to give up drinking for a month. At the end of the trial, the volunteers' body weight was down by an average of 1.5 per cent, and their blood pressure reduced by an average of 6 per cent. The most impressive drop was in their vascular endothelial growth factor (VEGF), which is a marker of cancer risk. It went down by a whopping 42 per cent.

At *Trust Me, I'm A Doctor*, we wanted to find out whether modest drinkers would get the same benefits from a dry month as the heavier drinkers, and whether they would continue to cut back once the abstinence

“DOES GIVING UP ALCOHOL FOR JUST A FEW WEEKS MAKE MUCH IMPACT?”



month was over. We recruited 26 volunteers, some who usually drank within the guidelines, others who were way over.

Before and after their dry month we gave them a health check. We measured liver fat, blood pressure, liver disease biomarkers and VEGF levels, among other things. As we also wanted to find out if giving up alcohol for a month affected their alcohol intake once they were free to return to drinking, we invited them to come back to be tested a final time, three weeks after their dry month was over.

All our volunteers stuck to their booze-free month and all saw health improvements – even those who normally drank less than the government recommended levels. Their VEGF levels, liver fat and weight all fell, while their quality of sleep, concentration and liver health improved. The effect was, not surprisingly, more pronounced in the volunteers who drank more than the government recommended guidelines of 14 units.

The lightest drinkers, having been off for a month, soon returned to drinking at their old levels. What was encouraging was that the heavier drinkers, who normally drank more than 14 units a week, did not. Three weeks after their dry month was over they were drinking, on average, 70 per cent less than they were before.

Yes, it was a small study that was done for a short period of time, but it certainly suggests that the heavy drinkers among you might think of taking a Dry January pledge. I may even join you this year. **🍷**



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EVE
ONLINE

Earth is just a distant memory, mankind has colonised the heavens and battles are raging throughout the stunning but dangerous, dystopian universe of New Eden. It's a land controlled by mega-corporations and home to the most powerful class of humans that have ever lived, the immortal Capsuleers. When you play Eve Online, a free massively multiplayer online (MMO) spaceship game, this is the community you find yourself immersed in.

If you think you know computer games, it's time to think again. Everything that happens in Eve Online is completely player-driven. It's the gamers who have created the history of New Eden, and the gamers who will shape its future - and there are now hundreds of thousands of them all over the world. As they compete for riches, power, glory and adventure, all of their actions will have consequences, either for themselves or other players in the game.

When in-game politics in EVE Online cause emotions to run high, it can spark huge battles and even wars. In January 2018, one battle involved 6,142 players – and resulted in EVE being awarded a Guinness World Record for the most concurrent players simultaneously involved in a single multiplayer Player versus Player video game battle.

When you start playing EVE Online, you create a character, pledging your allegiance to one of the four great empires – the devoutly religious Amarr Empire, the industrious Caldari State, the loyal and democratic Gallente Federation or the small but proud Minmatar Republic. Each has its own set of rules, aims and beliefs which shape how the community live, work and battle.

Stunning starscapes and nebulae, spaceports bustling with player activity and mysterious, unstable wormholes are all part of New Eden. As Eve Online players explore these vast solar systems, they pilot more than 340 different spaceships, ranging from the starter Corvette to the gargantuan Titans that lead the charge in engagements involving a multitude of gamers.

One of the most fascinating aspects of this game is that players are free to choose their own path. Some mine asteroid belts for desirable

resources that can be sold on the player market, others become traders, pirates or manufacturers, while others choose to focus on exploration or make their mark leading fleets into battle.

No matter what type of life players forge for themselves, they become part of a vast sandbox where it's impossible not to come into contact with other players. That might be in high-security space, policed by the non-player CONCORD organisation, or in low-security space where there really are no rules!

While it's true that one of the greatest achievements of EVE Online has been the unprecedented number of players coming together to outsmart their rivals, it's also just as much about each player's unique experience. Since this free game was launched 15 years ago, each and every player has contributed to the greater tapestry – and they will all continue to shape the future of this fascinating space adventure.

»» EVE ONLINE: «« STARTLING STATISTICS



More than 700
spaceships destroyed
every hour



More than 7,000
star systems
to explore



More than 1,000 pilots
jump between star
systems every hour



More than 2,500
hidden wormholes
to discover



More than 2.5 million
cm3 of ore is mined
every minute



1,600 spaceships
are produced
every hour



500 transactions take place on
the player market every minute



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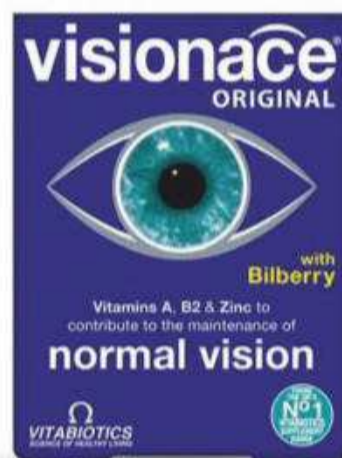


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INNOVATIONS

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DECEMBER 2018

EDITED BY HELEN GLENNY

OFF-ROAD ASTRONOMY

Sadly, you won't be able to buy this one-off model anytime soon



Nissan's taking observatory-class astronomy into the wilderness with this concept car, unveiled at this year's Hanover Motor Show. Developed in collaboration with the European Space Agency (ESA), the Nissan Navara Dark Sky has an ultra-high performance PlaneWave telescope in tow.

Once you're parked up, you can open the trailer's mechanical roof and focus the powerful telescope on distant galaxies, nebulae and

supernovas. To minimise disruption to your vision when you're observing at night, the car and trailer only use red light, and reflective orange piping on the seats provides visibility inside the vehicle.

"The Nissan Navara Dark Sky Concept allows observations to take place in remote places, avoiding light pollution, while also transporting telescopes safely and easily," says Fred Jansen, ESA's senior mission manager for Gaia.



WANTED

<p>1</p> <p>FEELING HOT</p> <p>Set the perfect temperature via an app, and this Ember ceramic mug will keep your tea or coffee hot for an hour. Perfect for those forgetful drinkers, who are always finding cold cups of tea around the house.</p> <p>Ember Ceramic Mug £79.95, ember.com</p>	<p>2</p> <p>ZIP IT</p> <p>Libratone's next-generation wireless speaker comes Alexa-enabled, with powerful 360° sound and a 12-hour battery. The Danish company is so proud of its design that you can zip the cover off the speaker to peek at what's inside.</p> <p>Libratone ZIPP 2 £279, libratone.com</p>	<p>3</p> <p>ROCK 'N' ROLL</p> <p>Connect your phone via Bluetooth and blast out your music through this speaker, or use the RCA input to hook it up to your record player. It beautifully blends new with old, and gives you a punchy sound that's probably louder than you need.</p> <p>Marshall Stanmore II Bluetooth speaker £299.99, marshallheadphones.com</p>
<p>4</p> <p>DIY DEVICE</p> <p>This kit gives you all the components of a smartphone and details on how to put it all together. The finished phone can run apps you code yourself, make calls, connect to Wi-Fi and Bluetooth, keep time and wake you up.</p> <p>MAKERphone From \$94 (£72.50 approx), makerbuino.com</p>	<p>5</p> <p>UNDERWATER BOOSTER</p> <p>The Trident underwater scooter has two propellers, a speed of 7km/h, and can dive to 49 metres. At 3.5kg, it's light enough to slip in your hand luggage, while its battery lasts 60 minutes – long enough for a snorkel among the sea creatures.</p> <p>Trident Water Scooter \$419 (£323 approx), geneinno.com</p>	<p>6</p> <p>CHARGED UP</p> <p>Fitbit's packed more features than ever into its latest Charge fitness tracker. It has a more accurate heart monitor and a relative SpO₂ sensor, which allows users to track blood oxygen levels and keep an eye on things like allergies or sleep apnoea.</p> <p>Fitbit Charge 3 From £129.99, fitbit.com</p>

GET DECORATIVE

Meet Scribit. It's a little robot that'll draw whatever you want on any vertical surface.

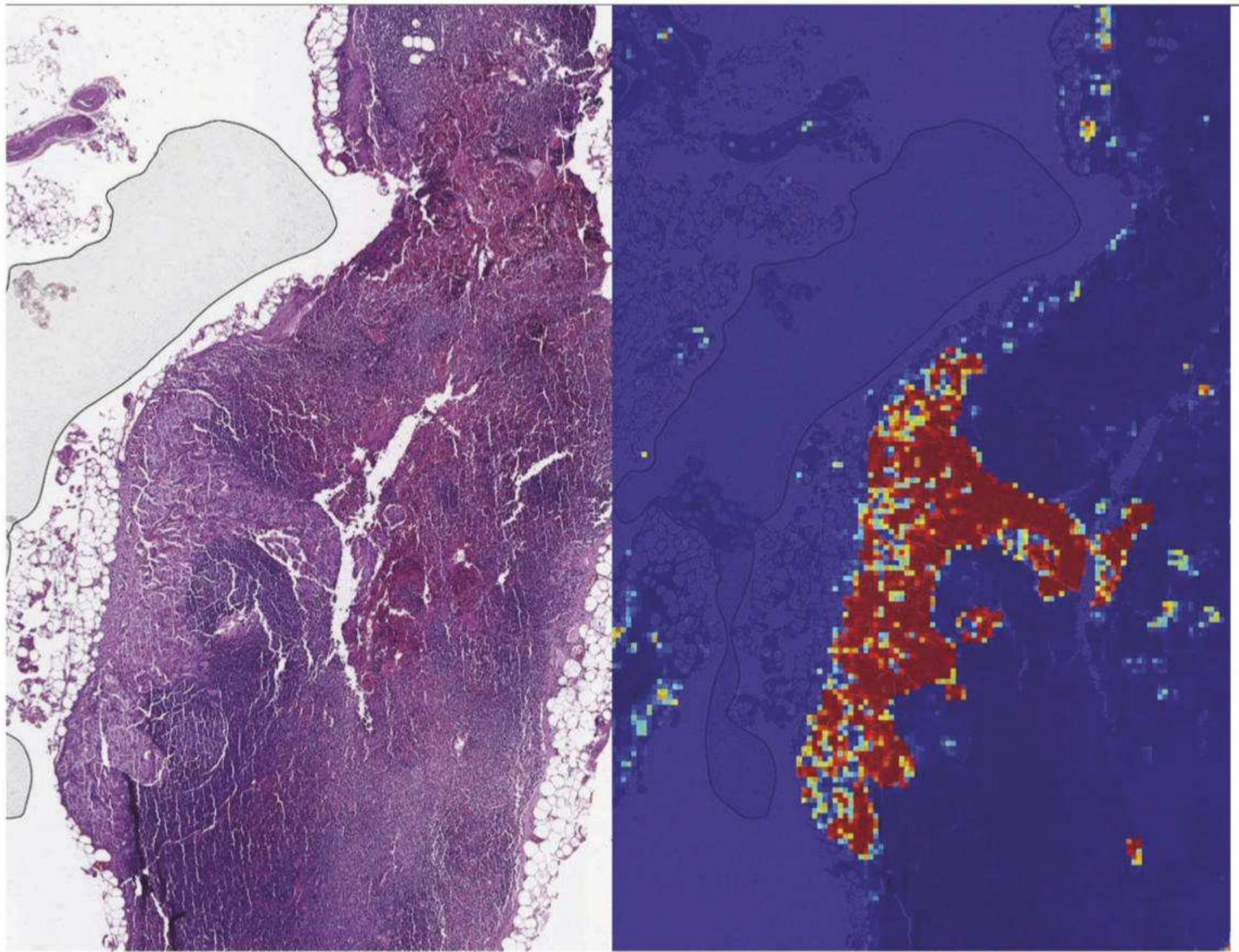
Connect to the app and browse a library full of designs, or import or create your own art for Scribit to draw. And if you don't like the design once it's on your walls, then don't worry – it's erasable. Scribit draws using a set of markers that are heat-sensitive. When instructed, Scribit will go back over its drawing with a heat pod, evaporating the ink.

The Scribit team suggests using it for decorating your home or doing presentations at work (graphs and charts look more interesting when drawn on the office walls with coloured markers, in our opinion).

Remember being told off for scribbling on the walls when you were a kid? Scribit could be the modern way to indulge that urge.

Scribit Wall-Writing Robot

\$399 (£308 approx), scribit.design



HEALTH

AI IS BETTER THAN DOCTORS AT DETECTING BREAST CANCER

The AI was shown a microscope slide containing lymph nodes (left), and it was able to correctly identify the tumorous region by highlighting it in red (right)

Google's deep learning AI has proven that it is more accurate than pathologists at detecting breast cancer that has spread to a patient's lymph nodes. The presence or absence of these 'nodal metastases' influence a patient's prognosis and treatment plan, so accurate and fast detection is important. But in some cases, only 38 per cent of small metastases are picked up by pathologists when samples are reviewed under time constraints, and right now, that pathologist's examination is the gold standard in diagnosis of nodal metastases.

Google customised one of its 'off-the-shelf' deep learning approaches, calling it LYNA (LYmph Node Assistant). Among other things, it was taught to examine the images at different magnifications, similar to how a pathologist examines slides. The algorithm's first test showed that LYNA was able to correctly distinguish a

slide with cancer from a slide without 99 per cent of the time, even when the regions were too small to be detected by pathologists. In the second, six pathologists completed a diagnostic test with and without LYNA's assistance. With LYNA's help, the doctors found it 'easier' to detect small metastases, and on average the task took half as long. Pathologists working with LYNA's assistance were more accurate than both unassisted pathologists and the LYNA algorithm working alone.

Google's researchers suggest that algorithms like LYNA could help with these identification tasks to allow more time for pathologists to work on more complex diagnoses. But for now, further testing is needed to determine if LYNA will work in real-life settings, which could involve a wider range of samples from different sites in the body.

TECHNOLOGY

THESE 3D-PRINTED SMART DEVICES DON'T NEED BATTERIES OR ELECTRONICS

Researchers at the University of Washington have developed 3D-printed objects that can transmit and store data about their use without the need for batteries or electronics.

The devices use a method called 'backscatter'. They have antennas embedded in them that reflect radio signals from something like your home Wi-Fi router. The way the antennas backscatter their signals carries information about how the object is being used.

The researchers suggest these could be used for devices like 'smart' pill bottles, to record when they're being opened or

closed. They could then send information to an app to help patients or doctors track their use. As the objects are completely made of plastic, users wouldn't need to worry about the objects getting wet, losing signal or running out of batteries.

The team has also created an insulin pen that uses a coiled-up spring to record how many times it's used when it's out of range of a Wi-Fi signal. When the user's back in Wi-Fi range they can release the spring, and data about the pen's use is sent to a device.

The next step is for the researchers to scale down the new technology so they can be tested in real healthcare situations.

TECH BYTES

**SELF-DRIVING SHIPS**

Rolls Royce is looking to make commercial shipping safer and more efficient by collaborating with Intel to make intelligent, self-driving ships. The vessels will be less prone to human error and better equipped to navigate and avoid hazards. They'll still have a crew on board, but they'll be freed up to focus on more valuable tasks.

ELECTRIC GUM

Japanese researchers have developed chewing gum that never loses its flavour. It uses the 'piezoelectric effect', where a material generates an electric charge when squeezed. When this gum is chewed, it creates a small electric current that tricks your tongue into experiencing different tastes. Don't expect raspberry ripple yet – testers report that the gum tasted of dried sardines.

BETTER SPECS

Wave your bifocals goodbye. TouchFocus, a Japanese company, has developed glasses that can change focus from short- to long-sighted. By touching a sensor on the frame, liquid crystals set in the lower half of the lenses alter the focus in that area. Tapping it again switches the focus back.

The University of Washington has developed this pill bottle and prosthetic hand that can transmit information about their use without the need for electronics

ON TEST: FEMTECH

WORDS: HELEN GLENNY & ALICE LIPSCOMBE-SOUTHWELL

Women's health tech is fast becoming a multibillion dollar industry, spearheaded by female innovators. We put some of their most promising products to the test...

The tech industry is still stubbornly male-dominated (in 2017, 79 per cent of venture capitalist funding went to all-male teams), but the proportion of female-led start-ups is on the rise.

Those companies are learning about the effect of hormonal fluctuations and menstrual cycles on women's health, innovating around pregnancy and breastfeeding, and tackling issues like postnatal depression and the disproportionate amount of women affected by Alzheimer's.

Meanwhile, apps and online shopping are making it easier for women to experiment with tech that might still be considered taboo. This emerging industry has been dubbed 'femtech', and market analysts Frost & Sullivan have recently forecast that it'll be worth \$50bn by 2025. We're testing three femtech products that address common issues: conceiving a child, menstrual pain, and stress urinary incontinence. Now that top innovators are tackling these issues, how much better off are we?

PELVIC FLOOR TRAINER

I feel a little silly standing in the bathroom trying to control a gemstone on my phone screen by squeezing my vaginal muscles. I'm testing the Elvie Trainer, which claims to help strengthen the pelvic floor by 'gamifying' pelvic floor exercises. Medical advice suggests that pelvic floor exercises, also known as Kegels, can be helpful in preventing incontinence due to ageing or childbirth.

The Elvie is discreet, pebble-shaped, and completely unintimidating. You simply pop it in, then sync it with the accompanying app via Bluetooth. The app uses real-time feedback to visualise your muscles as a gemstone icon on your phone screen. You then get led through exercises, across different levels, to give you a five-minute workout. For example, in one exercise you pulse your muscles to 'jump' the icon into targets, while in another you squeeze to hold the gemstone in a circle. **ALS**

£169, elvie.com



VERDICT

Pelvic floor weakness can occur after childbirth and the menopause, so I'm not quite the right market for the Elvie, as I've experienced neither. But I did find that it made boring pelvic floor exercises interesting, and it was fun to smash targets. The device says you can see results by doing regular workouts, but I kept forgetting to exercise as I couldn't get the app notifications to work.



PERIOD PAIN BLOCKER

Livia promises to take away my period pain, and for that, I'll put up with its bulky, palm-sized unit hooked on to the waistband of my jeans. It's a mobile TENS (transcutaneous electric nerve stimulation machine) device, which passes a current through electrodes placed on the skin. They cause a vibrating sensation that, according to 'gate control theory', stimulates the nerves making it impossible for the pain to pass. Livia also claims to help release beta endorphins, further easing pain. The sticky electrodes last multiple wears and are easy to put on and take off – you can pop them on your belly or lower back, depending on where you feel your pain. You can change the intensity of the stimulation, and although the vibrations feel weird at first, your nerves adapt rapidly and after a few seconds you stop feeling them. **HG**

£119, mylivia.com

VERDICT

Livia worked wonderfully for me on light period pain days, reducing the pain within minutes. But I get one can-barely-stand-because-of-the-pain day per cycle, and on that day I felt like I needed electrodes on both my belly and my back, whacked up to max stimulation. It would've taken at least two Livias to take my pain away, so I found myself reaching for the ibuprofen instead.

FERTILITY BRACELET

Ava is a bracelet you wear on your wrist every night, and sync to your phone every morning. It monitors your skin temperature, breathing rate, resting heart rate, heart rate variability and sleep patterns, and uses those variables to predict when you're ovulating. It takes a few months for the app to work at its best. For example, research says you're most fertile two or three days before your temperature rises, so the app needs to track temperature over time to correctly predict when you'll ovulate. Ava was tested in a year-long clinical study, and was found to detect an average of 5.3 fertile days per cycle, with 89 per cent accuracy. **HG**

£249, avawomen.com



VERDICT

The bracelet is comfortable to wear but doesn't hold charge well over multiple nights – so you have to pack your charger when you're on the move. Though I wasn't attempting to get pregnant, it identified my peak fertility window and became more accurate over time. In addition, it gave interesting sleep data (hours slept and percentage of light sleep compared to deep and REM) and helped me track my periods. It's a modern, more reliable version of graphing body temperature on a chart every morning like my mum did 30 years ago.

Three more products making waves in women's healthcare



WILLOW WEARABLE BREAST PUMP

Slip this breast pump into your bra for hands-free pumping. It's even quiet enough to use in a business meeting. Only available in the US for now.

\$479 (£350 approx), willowpump.com



HANX FAIRTRADE CONDOMS

HANX vegan condoms are designed for women's comfort as well as men's. They're discreetly branded and available by subscription service straight to your door.

£4.99 for a pack of three, hanxofficial.com



THINX PERIOD-PROOF UNDERWEAR

THINX absorbent, reusable underwear can replace, or be used with, pads, tampons or cups. Its antimicrobial lining fights bacteria, and it can hold two tampons' worth of fluid.

From £19, shethinx.com

“

Sennheiser's exquisite
MOMENTUM True
Wireless sets a new
benchmark for audio
quality, comfort
and craftsmanship

”



PURE PERFECTION

Sennheiser's latest addition to the MOMENTUM range proves that it is possible to have exceptional sound and total freedom

Think of Sennheiser and you think of a company that's always at the forefront of new audio technology. Driven by an innovative culture and unbridled passion for producing groundbreaking designs, it doesn't just look to the future, it reinvents it.

Now it's back with a new addition to its flagship range – the MOMENTUM True Wireless premium earbuds. You're right in thinking that these aren't the first wireless earbuds to hit the market, many have gone before – but it's quite possible that these are the best.

That's the unique thing about Sennheiser. Rather than rush to be the first to bring a product to market, it's happy to spend time perfecting it – only offering it to customers when it's absolutely sure it can't be bettered. For these new MOMENTUM True Wireless premium earbuds, that time is now.

INTRODUCING MOMENTUM TRUE WIRELESS

Listen and you'll hear why these earbuds are head and shoulders above many others. Uncompromised sound performance, state-of-the-art technology and refined design all come together to offer a new dimension in wearable sound. Here's how:



EXCEPTIONAL SOUND

Experience the legendary Sennheiser sound loved and revered by audiophiles, brought to you by 7mm dynamic driver technology.

WIRELESS FREEDOM

Completely wireless, these earbuds are Bluetooth 5.0 compliant and give stable connectivity, lag-free audio and a superior streaming experience.

UNBELIEVABLE COMFORT

These lightweight and splash resistant earbuds are ergonomically designed for a perfect fit and total comfort no matter how long you wear them.

CRAFTSMANSHIP

The earbuds are finely sculpted to offer durability, timeless elegance and finished with beautiful metallic details.

TRANSPARENT HEARING

Connect with your surroundings and hear what's going on around you, or have conversations without having to remove your earbuds.

TOUCHPAD CONTROL

The intuitive touch interface on the earbuds lets you control your music, answer phone calls or access your voice assistant with a single tap or swipe.

LONG BATTERY LIFE

Use your earbuds all day long – the 4 hours of battery life can be extended to 12 hours with on-the-go charging via the compact case.

BUILT-IN EQUALIZER

An integrated internal equaliser lets you personalise your audio sound straight from any Bluetooth audio source.

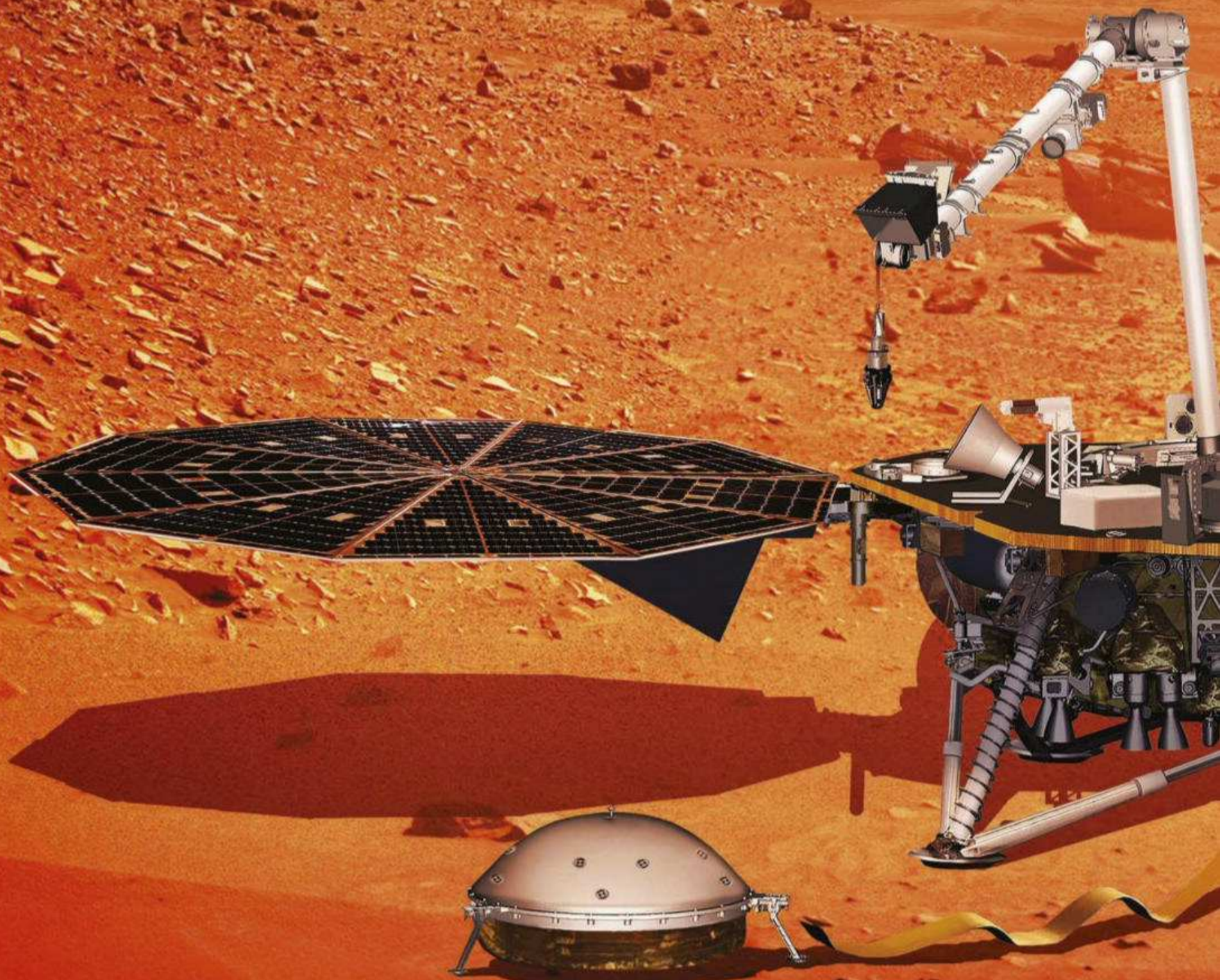
SMART USER INTERFACE

Automatic pairing makes it easy to set up your earbuds right from the start and the auto on/off function gets the music playing as fast as possible.



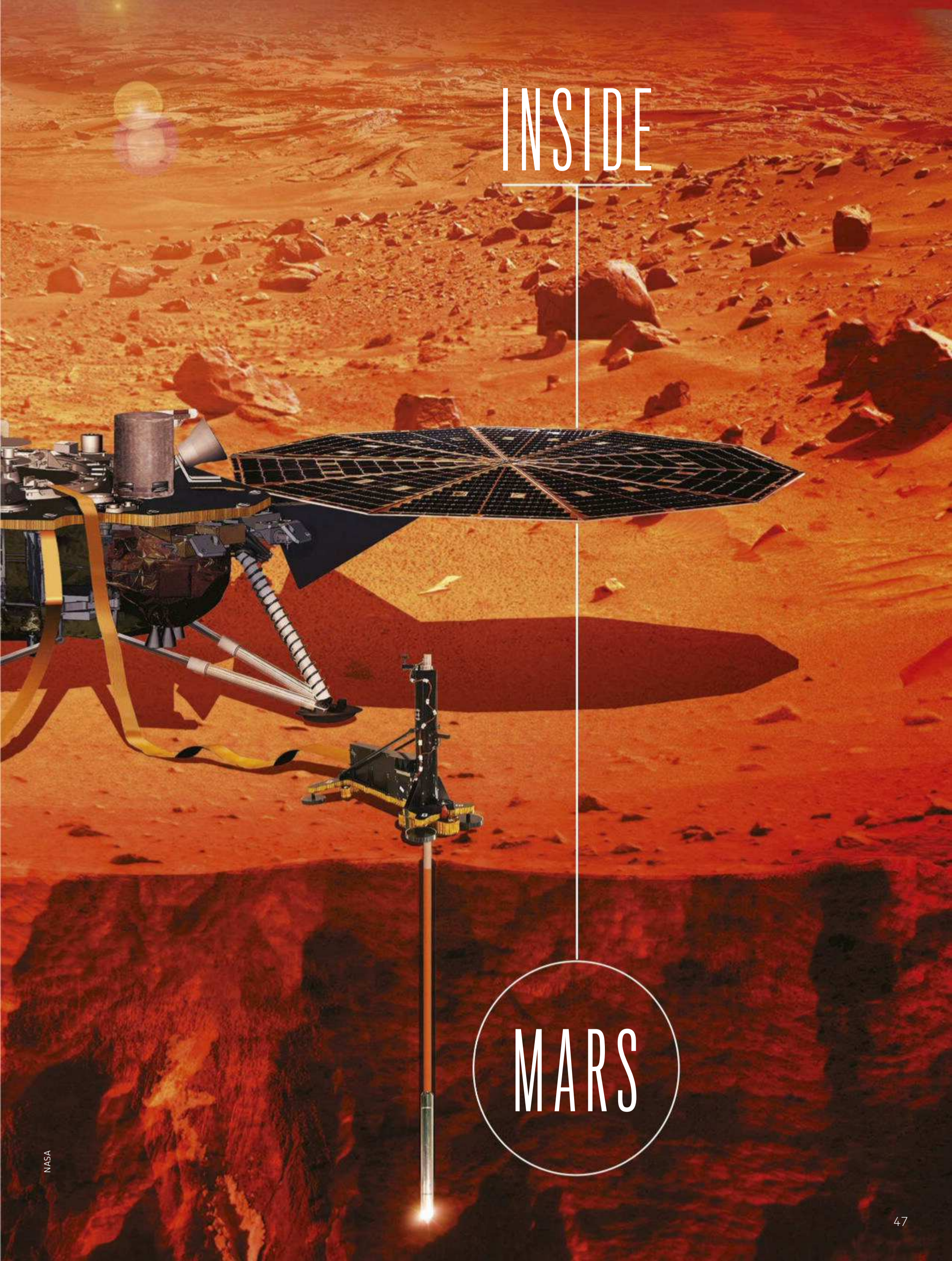
Available at all major
retailers and [Sennheiser.com](https://www.sennheiser.com)





The Red Planet has been an object of intrigue for centuries, and an armada of orbiters and rovers have explored Mars up close. Yet for all our exploration efforts there remains a perplexing mystery: just what is going on deep within Mars?

WORDS: COLIN STUART



INSIDE

MARS

Previous missions to Mars have been biased towards what's happening on the surface. That's no surprise given the menu of marvels on offer, such as sweeping sand dunes, soaring volcanoes and scintillating blue sunsets. We now know Mars's outer facade so well that we have a better map of the Martian surface than we do of the ocean floor here on Earth. Yet it's the deepest layers of a planet that really make it tick, and relatively little is known about the Red Planet's interior. Now, that's all about to change thanks to a mission that has been long in the planning. "It was first proposed 25 years ago," says Dr Suzanne Smrekar from NASA's Jet Propulsion Laboratory in California. "We're excited to finally be doing this." Smrekar is the deputy principal investigator for the InSight mission. It was launched in May aboard an Atlas V-401 rocket from Vandenberg Air Force Base in California and is currently en route to the Red Planet. Due to touchdown on Mars on 26 November, close to NASA's existing Curiosity rover, it will spend a minimum of one Martian year (nearly two Earth years) surveying deep beneath the famously ruddy dirt.

The goal of InSight is to give Mars's interior the planetary equivalent of a full body health check. It will take its 'pulse' by carefully monitoring seismic activity (otherwise known as 'Marsquakes') and record its temperature by keeping track of the heat flow under the planet's surface. That will help us understand how rocky planets, such as Earth and Mars, formed in the first place. On Earth, most of these clues have been erased due to the action of our tectonic plates over billions of years. While seismic activity has been measured on the Moon, thanks to instruments left by the Apollo astronauts, it's a much smaller world and it formed in a different way to the Solar System's four rocky planets. Mars could hold secrets about how we came to be here in the first place, and InSight hopes to find them. "Mars is the perfect place for us to learn about terrestrial planet formation and evolution," says Smrekar.

TOUCHDOWN ON MARS

The lander itself is based on NASA's Phoenix probe that touched down close to the Martian north pole in May 2008. By closely following a previous design, mission scientists have kept costs down. Since InSight will initially strike the Martian atmosphere



"Mars is the perfect place for us to learn about terrestrial planet formation and evolution"

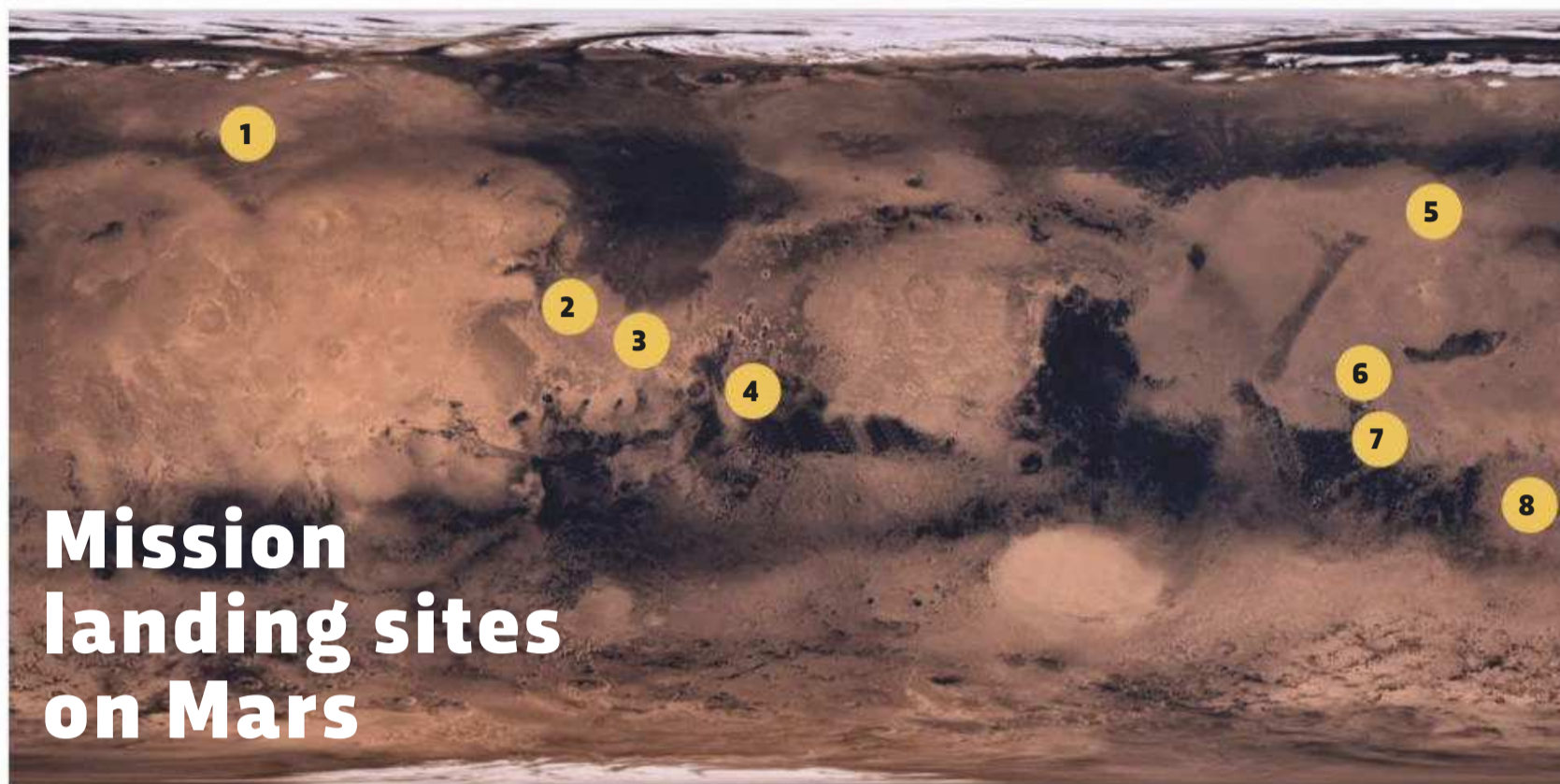
ABOVE: The Mars InSight mission preparing for liftoff in May 2018

TOP RIGHT: Map of mission landing sites on the Red Planet

MIDDLE RIGHT: The InSight lander will be digging beneath the surface of Mars

BOTTOM RIGHT: Mars's atmosphere could have been obliterated by the solar wind, as depicted in this illustration

at over 10,000 kilometres per hour, the craft has an outer shell that will shield the sensitive equipment from the heat generated by friction with Mars's thin atmosphere. A parachute will then deploy to lower InSight down through the bottom half of the Martian atmosphere, then rockets will fire when it is 100 metres above the surface to gently deposit it onto the Red Planet. While Phoenix's landing went smoothly, that's no guarantee of a hiccup-free ride this time around – landing anything on Mars is a notoriously tricky business. "A third of previous Mars missions have been unsuccessful," says Smrekar. Still, she's confident that their well-tested system has a 99 per cent chance of sticking the landing within the 130km-wide designated touchdown zone in a flat plain known as the Elysium Planitia. Sixteen minutes after landing, the Martian dust will have settled back down, after which InSight's solar



Mission landing sites on Mars

1. PHOENIX – 2008
2. VIKING 1 – 1976

3. PATHFINDER – 1997
4. OPPORTUNITY – 2004

5. VIKING 2 – 1976
6. INSIGHT – NOV 2018

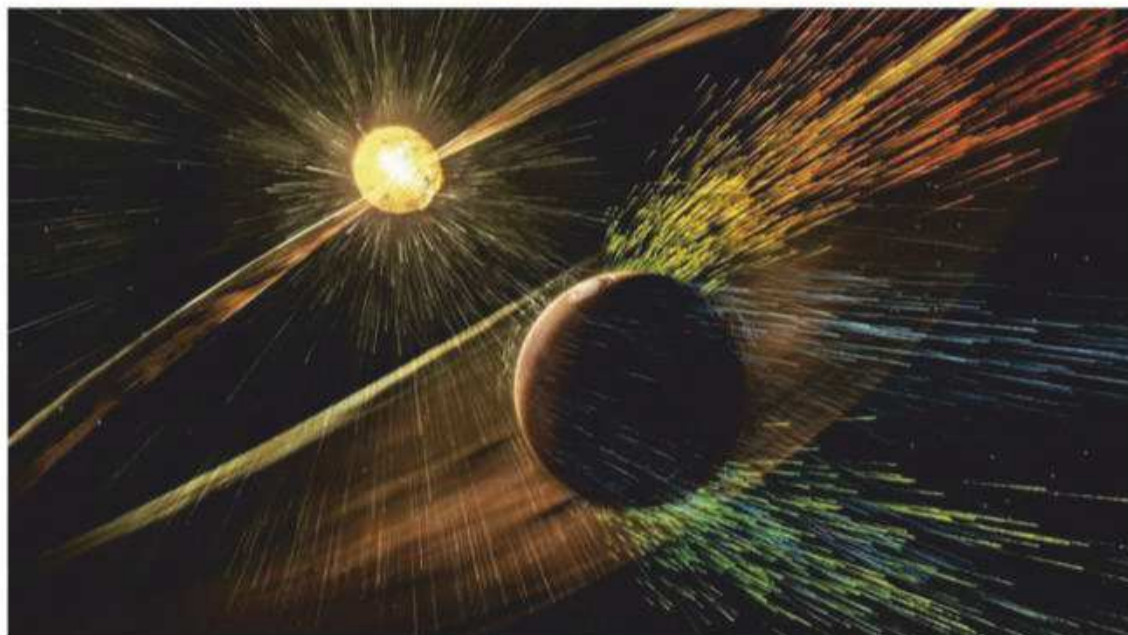
7. CURIOSITY – 2012
8. SPIRIT – 2004

arrays will whirr into action to unfurl and charge its solar panels. Then the mission begins in earnest.

Elysium Planitia was chosen due to it ticking so many boxes. “First there were the engineering constraints,” says Smrekar. The landing site had to be less than two kilometres above Martian ‘sea level’ so that the probe travelled through enough atmosphere to slow it down. Equally they wanted a wide, open space free of large rocks and other potential obstacles. It also had to be close to the Martian equator so that the probe can bathe in enough sunlight to stay powered for at least a Martian year (687 Earth days) – the minimum intended duration of the mission, Smrekar says. She does, however, caution against expecting the stunning pictures of sweeping Martian landscapes that we’ve become accustomed to with missions like Spirit, Opportunity and Curiosity because InSight’s mission scientists care about what’s under the surface of the planet, not what’s on it. “It’s a flat, boring site,” Smrekar says. “There were only a couple of sites that met all these constraints.”

TESTING, TESTING

One of the key instruments on board is a seismometer (known as SEIS) for measuring tremors from deep within the bowels of Mars. For Dr Neil Bowles, from the University of Oxford, it’s the most exciting part of the mission. The thing he’s looking forward to most, he says, is “the first unequivocal detection of a Marsquake”. One of the Viking landers of the 1970s ➤

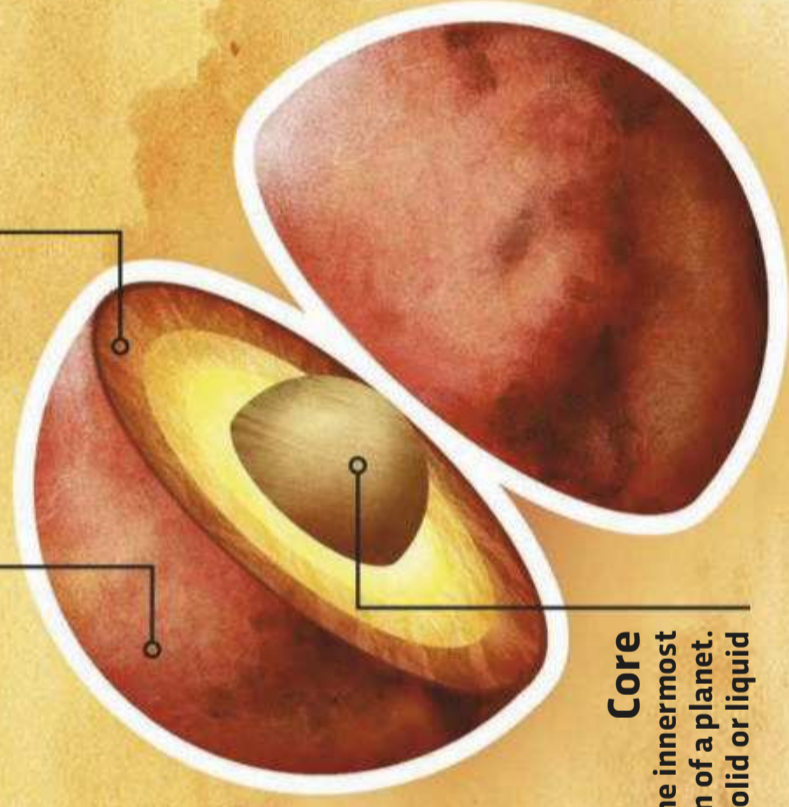


THE INSIGHT MISSION

ILLUSTRATION: Lost Studio

Mantle
Found inside some rocky planetary bodies, beneath the crust

Crust
Outer layer of planet



Core
The innermost region of a planet. Can be solid or liquid

Mars's distance from Earth varies between

54.6 million km and

401 million km

There are rocks on Mars named after cartoon characters including

Scooby-Doo and Yogi Bear

Ice on Mars sublimates rather than melts – it goes straight from ice to vapour, skipping the liquid phase

Mars is home to Olympus Mons, the Solar System's tallest volcano with a height of approximately

26km

Everest is 8.8km tall

Phobos, Mars's largest moon, rises and sets twice each Martian day

In the past, Mars likely had liquid oceans covering at least one-fifth of its surface

38%

The surface gravity on Mars compared to what we experience on Earth

1 SEIS

This instrument for measuring Marsquakes is sensitive enough to pick up tiny vibrations the size of a hydrogen atom.

4 TETHERS

Cables through which data and commands can be exchanged between the deployed experiments and main body of the lander.

7 TWINS

This stands for Temperature and Winds for InSight – essentially they're weather stations for monitoring prevailing atmospheric conditions.

2 WTS

The Wind and Thermal Shield will help protect the SEIS instrument while it is in contact with the Martian surface conditions.

5 RISE

The Rotation and Interior Structure Experiment measures the probe's position and Mars's wobble to reveal the planet's inner structure.

8 UHF ANTENNA

Ultra-high frequency antenna that allows communication between InSight and orbiting spacecraft that can relay data back to Earth.

3 SOLAR PANELS

Based on the design of the Phoenix lander, these should provide enough power to last a Martian year.

6 PRESSURE INLET

This wind-shielded opening allows the lander to make measurements of Mars's atmospheric pressure conditions.

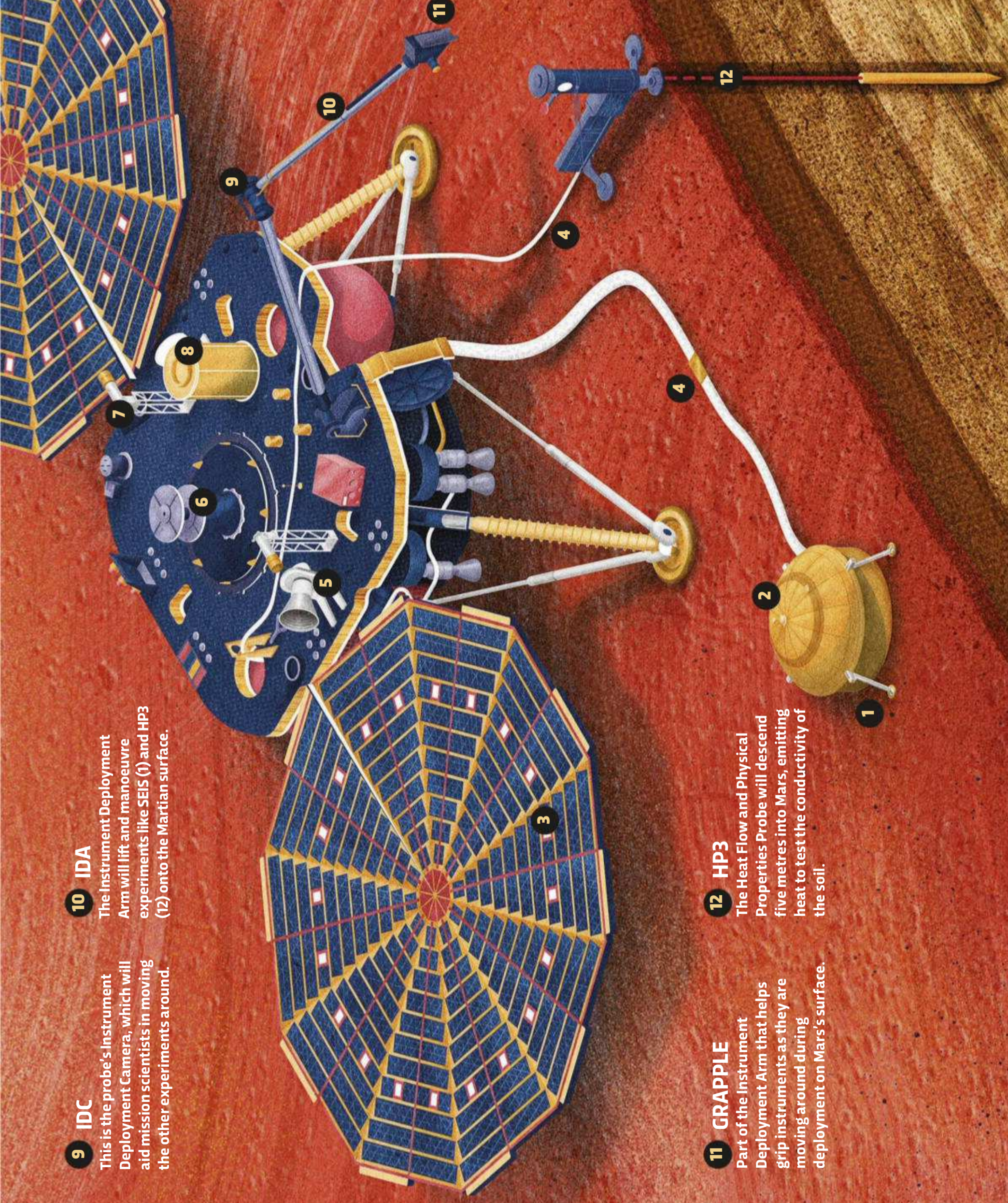


9 IDC

This is the probe's Instrument Deployment Camera, which will aid mission scientists in moving the other experiments around.

10 IDA

The Instrument Deployment Arm will lift and manoeuvre experiments like SEIS (1) and HP3 (12) onto the Martian surface.

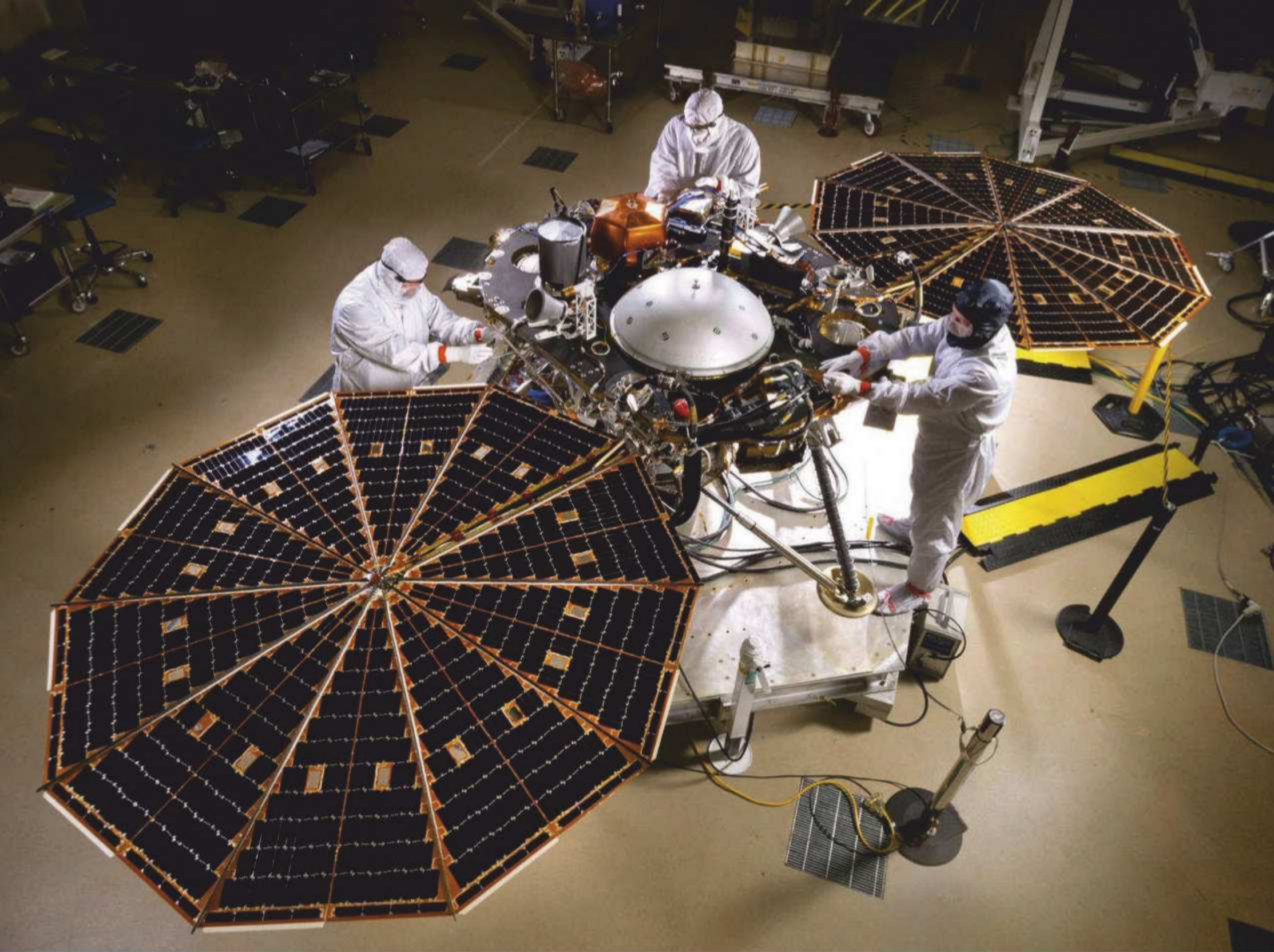


11 GRAPPLE

Part of the Instrument Deployment Arm that helps grip instruments as they are moving around during deployment on Mars's surface.

12 HP3

The Heat Flow and Physical Properties Probe will descend five metres into Mars, emitting heat to test the conductivity of the soil.



ABOVE: In a clean room, the solar array on InSight is deployed for testing

RIGHT: Assembling the SEIS instrument for measuring Marsquakes

● did carry a seismometer, but, crucially, it wasn't put in direct contact with the Martian surface. According to Bowles, that meant any tremors were felt through the legs of the lander and were therefore hard to measure accurately. It was better suited for sensing the fearsome Martian winds, but not for picking up underground vibrations. This time InSight's seismometer will be placed in direct contact with the ground and covered with a thermal shield to protect it both from the wind and wildly swinging Martian temperatures. It is so sensitive that it can pick up vibrations smaller in size than the width of a hydrogen atom. That's more than enough to also detect the telltale thump of meteorite impacts on the Martian terrain.

SEIS has already been fired up on the journey to Mars to test its sensitive instruments in the harsh environment of space, but the first full seismic data will start to trickle back to Earth in early 2019, a couple of months after the probe touches down. "Whatever we find will be interesting and exciting straight away, as so little is known about what's going on down there," says Bowles.

It's been over 130 years since similar measurements were made of earthquakes here on Earth, and our

knowledge about our planet's innards has been transforming ever since. "From the way vibrations are reflected and refracted inside the Earth, we've learned about its inner structure," Bowles says. Without ever travelling down inside our planet, we know that it has a solid iron inner core encased in a liquid outer core, which in turns sits beneath the mantle and then finally the crust. InSight may bring the same level of knowledge about Mars, and in doing so shed light on one of Mars's greatest mysteries: what happened to its magnetic field.

FIELD WORK

Earth's magnetic field is generated by the movement of material in the liquid outer core as the planet spins. There's weighty evidence that Mars once had a global magnetic field too, but now all that remains are scant patches of localised magnetism scattered here and there. It could be that, as Mars is a smaller planet, there wasn't enough material crushing down on the core to keep it liquid. If it solidified, there would no longer be movement, so the magnetic field would have switched off. Magnetic fields protect planets from the solar wind, which is a stream of charged particles blowing out from the Sun. Once

“Whatever we find will be interesting and exciting straight away, as so little is known”

Mars had no magnetic field, the solar wind was able to peck away at the planet’s atmosphere.

It is hoped that InSight can use the way vibrations travel through Mars to determine whether any of its core is still liquid. Understanding the link between the core and Mars’s magnetic field could prove crucial if we’re to regularly send astronauts to Mars and protect them from the harsh radiation generated by the Sun and the rest of the stars in the Milky Way. InSight might also reveal sub-surface reservoirs of water, kept as a liquid by heat rising up from the core. It might be the only place on Mars where its ancient water has been able to survive in liquid form. If life got started on Mars in its more temperate past, it may just still be clinging on in these subterranean seas. The stakes are high.

HOT TOPIC

If SEIS is the equivalent of a doctor’s stethoscope, listening for the planet’s beating heart, the Heat Flow and Physical Properties Probe (known as HP3) is like putting a thermometer under Mars’s tongue. Smrekar describes it as “a self-hammering nail”. The whole experiment weighs only three kilograms and will send back just over 40 megabytes of data over the duration of the mission – around the same as a low-quality YouTube video. Like a mole, it will

burrow down into the Martian soil to a depth of five metres – far deeper than any Mars probe before it. According to Smrekar, that’s deep enough to get away from any surface temperature variations due to day and night or Mars’s swinging seasons. Every 50 centimetres, the probe will let out a heat pulse and measure how that pulse dissipates through the Martian sub-surface. The quicker it fades, the better the surrounding material is at conducting heat – a surefire way to know what it is made of.

HP3 is also on the hunt for evidence of heat generated by radioactive decay. Elements such as uranium, thorium and potassium spontaneously break down over long periods into lighter elements, releasing energy along the way. It is thought Mars and Earth formed in a similar fashion from “planetary building blocks crashing together and melting,” says Smrekar. If the two planets formed from the same material, then we should expect a similar heat signature as those materials undergo radioactive decay. “InSight will tell us if the heat coming out of Mars is consistent with that picture,” says Smrekar.

That leaves the Rotation and Interior Structure Experiment (RISE), which measures the medical equivalent of the planet’s reflexes. As Mars orbits the Sun, it wobbles on its axis much like the Earth. Exactly how it wobbles depends on what’s going on in the centre of Mars. You can test this for yourself by comparing how a raw egg spins compared to a hard-boiled one. A partially liquid Martian core would lead to a different wobble compared with a solid core. So measurements from RISE will complement those from SEIS in order to shed light on the enigma of why Mars’s magnetic field shut off. The instrument will accurately track InSight’s position in space every day of the mission by sending a signal from Earth and having it reflected back home by RISE. Changes in Mars’s position and speed will leave telltale shifts in the frequency of the signal, just as the pitch of an ambulance siren changes as it hurtles past you.

If all goes to plan, and these experiments all work as intended, we’ll finally get crucial information about the most unexplored part of the most explored planet in the Solar System. 🚀

Colin Stuart is an astronomy speaker and author. His latest book is *How To Live In Space* (£16.99, Andre Deutsch Ltd). He tweets from @skyponderer.

ON THE PODCAST

Listen to our interview with Bruce Banerdt, the principal investigator for Mars InSight, on the *Science Focus* podcast. Visit sciencefocus.com/sciencefocuspodcast





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4GB GeForce GTX 1050 Ti
1TB SEAGATE 7mm SATA HDD
(5,400)
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THE NUCLEAR RENEGADES

A growing number of start-ups want to create and commercialise nuclear fusion, to generate clean energy for all. Can they succeed where the big guns have failed?

WORDS: PHILIP BALL

NUCLEAR FUSION

FACT CHECK

Plasma is the fourth state of matter, after solid, liquid and gas. It is electrically charged and can be generated by either heating a gas or subjecting it to a strong electromagnetic field.

After a short journey, I've arrived at a bland industrial park just outside Abingdon in Oxfordshire. It's populated by retailers of kitchen units and courier service companies, so it seems like an unlikely place for me to find an answer to the energy crisis. But within one of these anonymous warehouses, a company is seeking to recreate and harness the power of the Sun.

Tokamak Energy is building a device that looks like a steampunk submersible from a Jules Verne novel. Made from gleaming steel, it has glass-covered ports through which you can peer into the interior. Called ST40, it is still in the process of being assembled after its relocation from Tokamak's previous premises. But once it is up and running, you wouldn't want to be here. It will host a hydrogen plasma 10 times hotter than the centre of the Sun, with the aim of achieving nuclear fusion. When it was previously operating, says the company's executive vice chairman Dr David Kingham, it was briefly the hottest place in the Solar System.

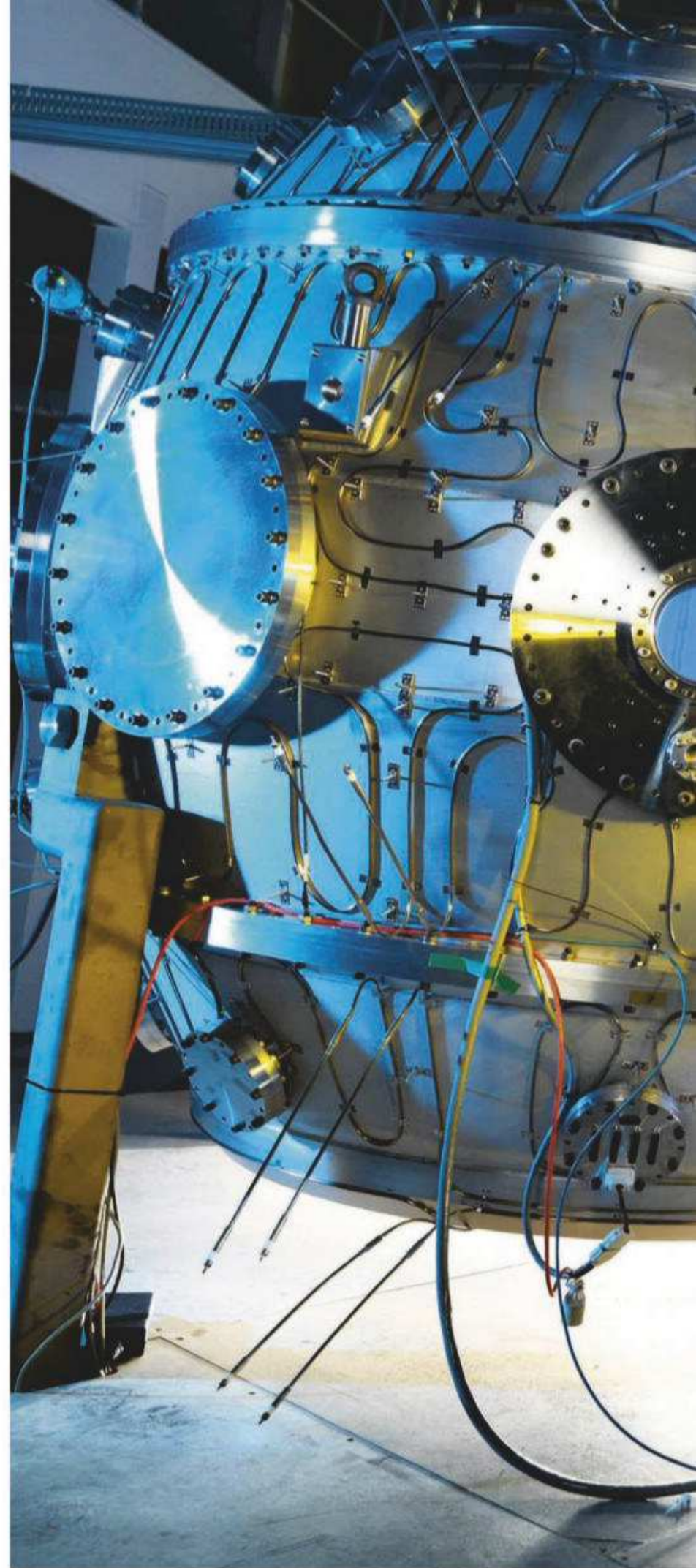
Tokamak Energy, with around 50 employees, is one of several small companies worldwide that believes the answer to the long-standing problem

“Fission happens naturally, fusion is harder to trigger – even though it powers the stars”

of how to harness nuclear fusion may come from fleet-footed private start-ups, rather than the gigantic international projects that have been trying to crack it for decades. As the global population soars, world energy consumption is expected to grow by around 30 per cent by 2040. Nuclear fusion has long been touted as a potential fix for this crisis, as it's capable of releasing millions of times more energy than burning fossil fuels. What's more, it doesn't depend on the weather – unlike many sources of renewable energy.

A STAR IS BORN

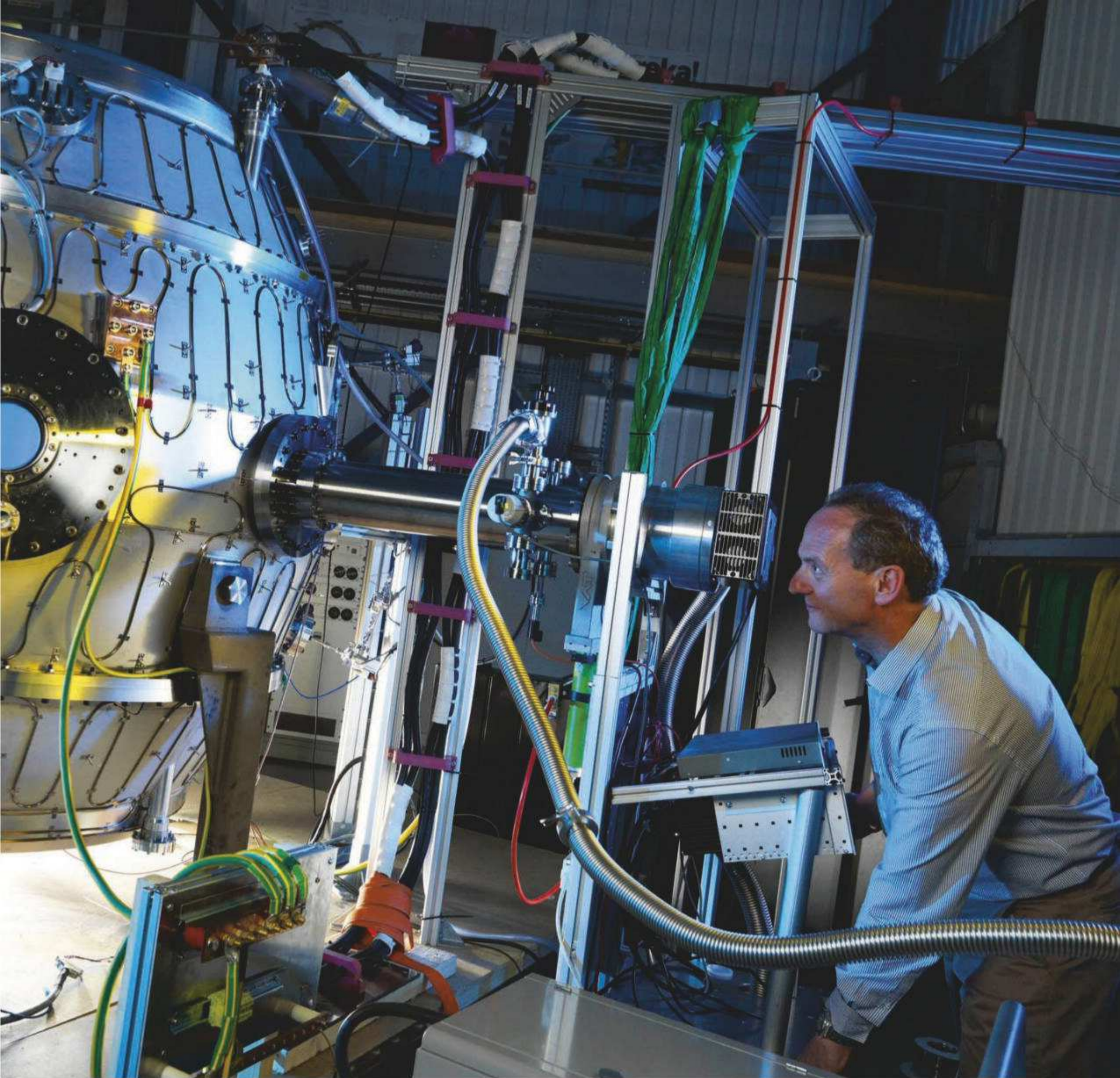
Nuclear fusion energy generation is saddled with the reputation that it has been 'only 20 years away'



for the best part of six or seven decades. But this time, advocates are convinced, it's different.

All current nuclear power plants use the process of nuclear *fission*: the release of energy when heavy radioactive elements such as uranium decay into other elements. With nuclear *fusion*, on the other hand, the energy comes not from the splitting of heavy atoms, but by the merging (fusion) of light elements such as hydrogen to make heavier ones. Both processes convert a little of the atoms' mass to energy, and Albert Einstein's famous equation $E=mc^2$ shows that even a tiny mass change can release awesome quantities of energy.

Both forms of nuclear energy generation are 'greener' than burning fossil fuels, in that they don't



produce greenhouse gases such as carbon dioxide. Fission, however, has its problems. Both the spent fuel and the radioactive emissions that ‘activate’ other reactor materials produce large amounts of radioactive waste that will remain hazardous for hundreds of thousands of years, and its disposal creates problems that the nuclear industry is still wrestling with.

In principle, nuclear fusion offers a better alternative. The products in this case are not radioactive, so there is little hazardous waste. And the energy release in fusion can be greater, as illustrated in thermonuclear hydrogen bombs where the process is unleashed in an uncontrolled outburst. But whereas fission happens naturally in stuff like

uranium that can be dug from the Earth, fusion is harder to trigger – even though it powers the stars.

An atom of hydrogen has one proton and no neutrons in its nucleus. The easiest way to fuse hydrogen atoms involves two of the element’s forms. One of these is called deuterium, which has a neutron in its nucleus as well as the proton, and tritium, which has two neutrons and a proton. Deuterium occurs naturally – it makes up about 1 in every 6,000 hydrogen atoms in seawater, so its supply is virtually limitless. But tritium decays radioactively, and needs to be produced in situ to fuel a fusion reactor.

To spark the fusion process and overcome the particles’ natural repulsion, the deuterium ►

ABOVE: Tokamak Energy’s ST40 tokamak is spherical in shape, making it more efficient than traditional cylindrical tokamaks

NUCLEAR FUSION

☛ and tritium must be heated to extremely high temperatures and either squeezed to tremendous pressures or kept hot for a long time. Such conditions exist in the Sun, and can be created artificially in experimental fusion reactors. But it's immensely hard to sustain and control those conditions, and for decades efforts to produce nuclear fusion in this way have consumed more energy than they generate.

The leading candidate for a fusion device is the so-called tokamak, first developed in the Soviet Union in the 1960s (the word is a Russian acronym). Here, a doughnut-shaped ring of hot plasma is suspended in space using strong electromagnetic fields – the plasma is too hot to simply 'bottle' in a way that brings it in contact with material walls. But the plasma is difficult to control, and easily becomes unstable in ways that destroy the intense conditions needed to keep fusion going.

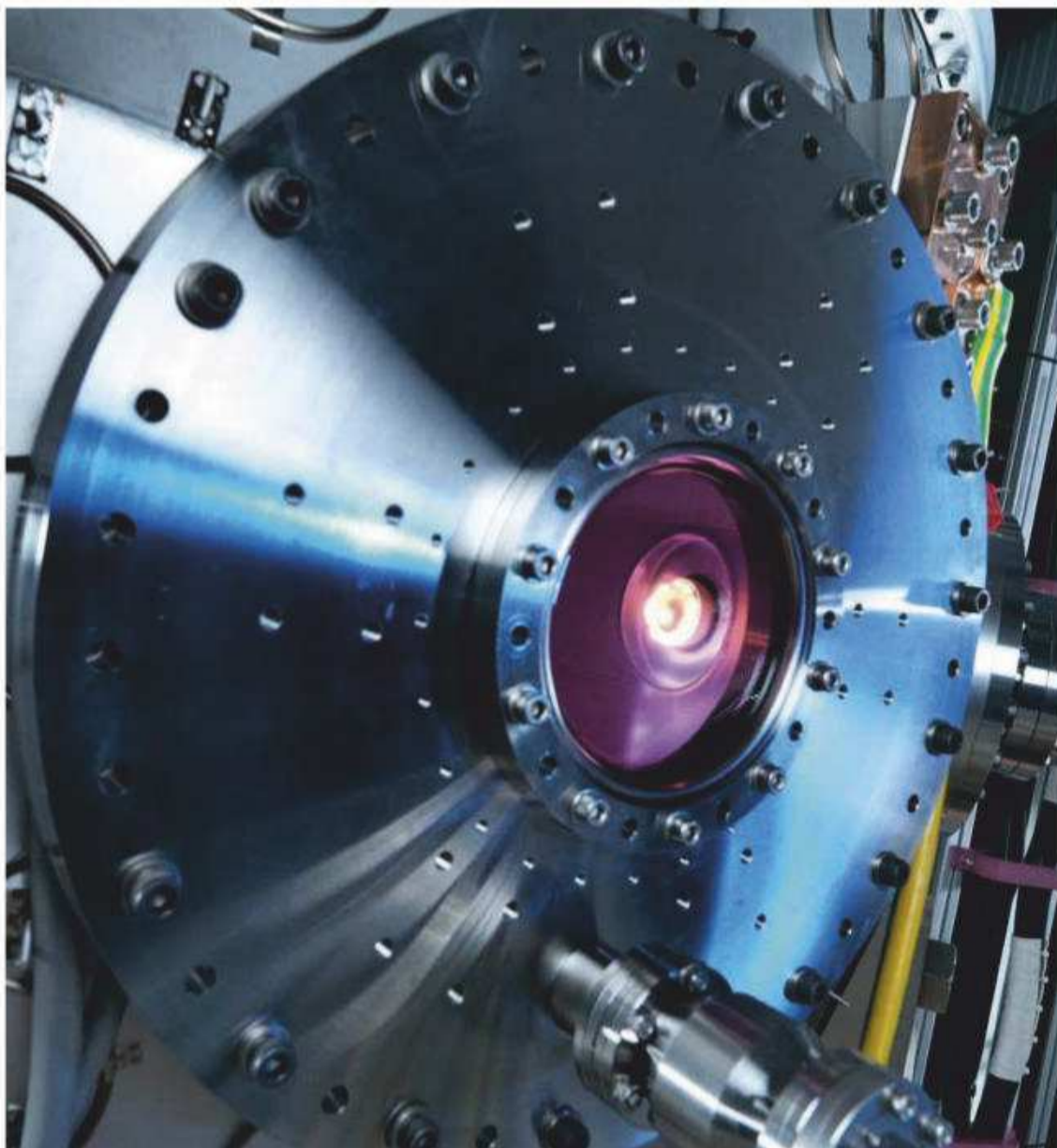
In other words, it's not getting controlled fusion underway that's the problem, but sustaining it to produce net energy gain. "It's a problem of engineering," explains Close. "Fusion has been demonstrated back in 1947, and has been going on in tokamaks for decades." But it still hasn't given us commercial fusion as a 'clean' source of energy.

THINKING SMALL

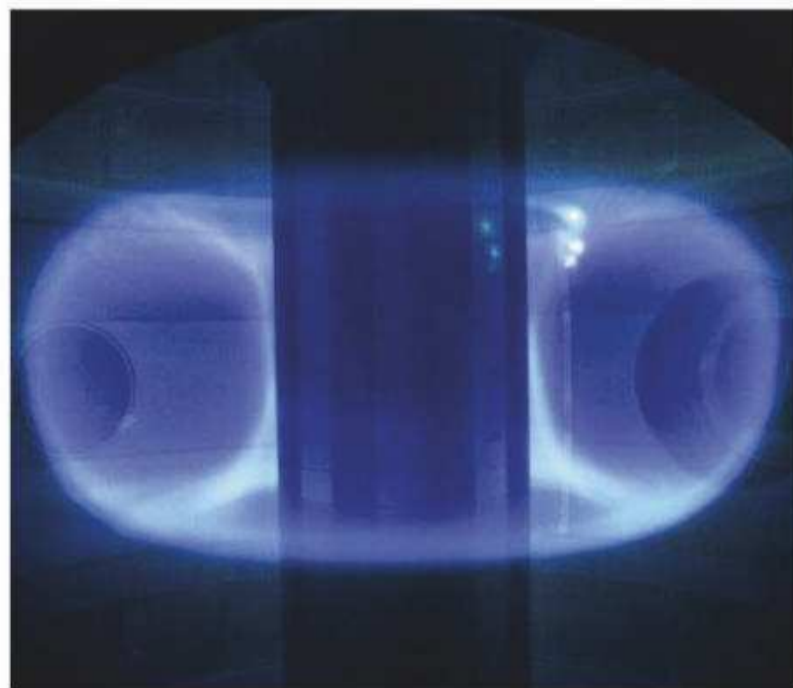
Global investment in nuclear fusion research (not including weapons-related research) is around \$2bn (£1.56bn approx), says Kingham. More than 40 experimental tokamaks are being tested and developed at many large centres and projects worldwide, such as the International Thermonuclear Experimental Reactor (ITER) in southeast France and the Joint European Torus (JET) in Culham, Oxfordshire, close to Tokamak Energy's headquarters. The EU's Roadmap to Fusion Energy predicts that a demonstrator plant based on the ITER reactor (called DEMO, and still under design) will put electricity into the grid around 2050, and that commercial plants will appear in the following decades.

It's a long wait, but the Tokamak scientists think they can get there quicker. In 2015, one of the company's consultants, physicist Dr Alan Costley, proposed that tokamaks small enough to fit onto the back of a truck might have significant advantages over big ones in producing energy gain. The conventional view is that tokamaks have to be huge to keep the plasma hot enough for long enough, but Costley argued that small tokamaks can operate at higher plasma densities, making them more efficient without needing to get larger.

The idea caused much debate and controversy in the fusion community, but Tokamak is counting on smaller reactors being the key to success. Devices of this scale are within the means of private investment – which in Tokamak's case has come from companies such as Oxford Instruments and Legal & General, as well as from initial seed funding from the UK government and private investors.



ABOVE: You can peer through the 'port holes' of the ST40 tokamak to see the doughnut-shaped ring of plasma (right) suspended inside by electromagnetism



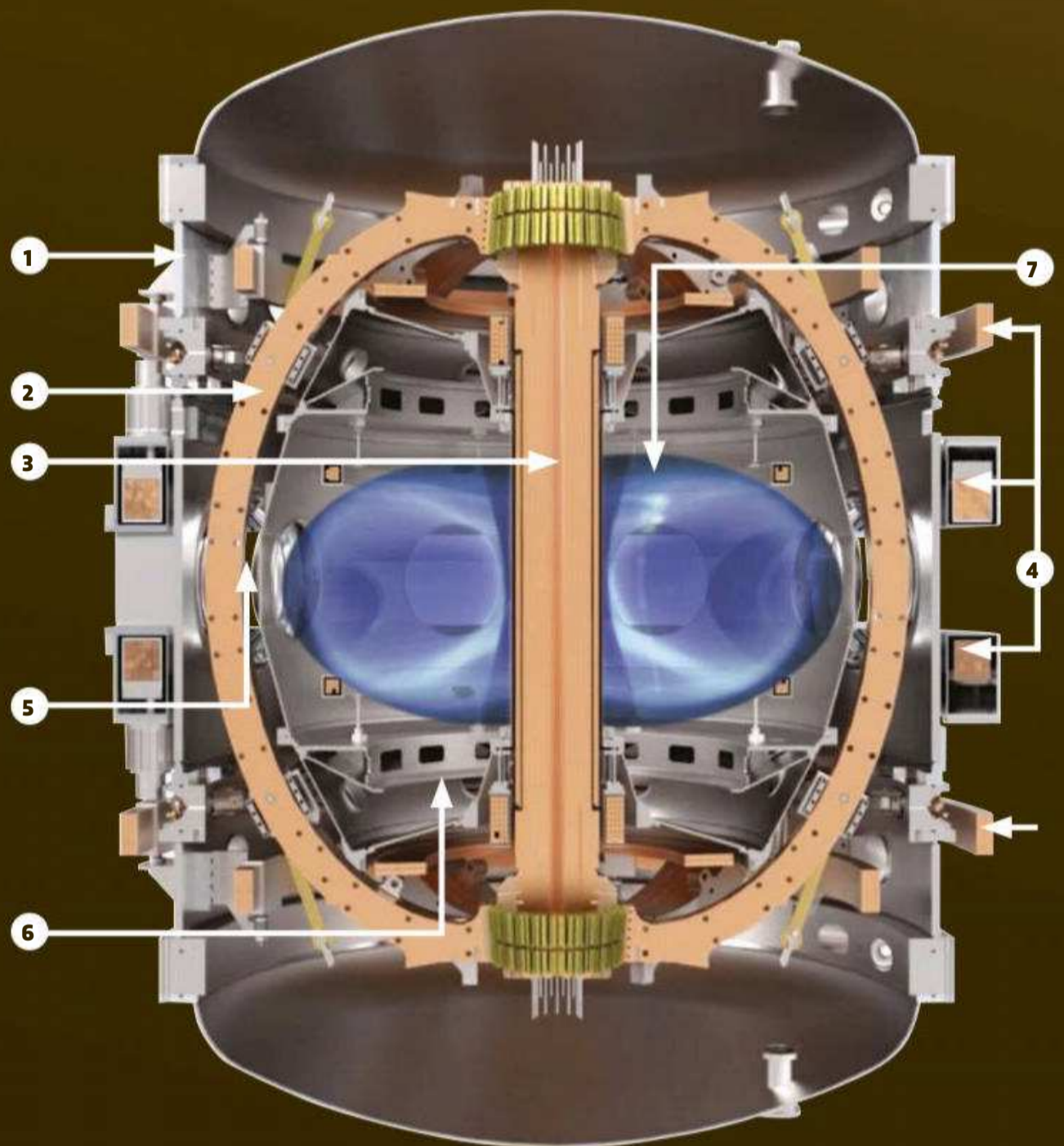
To generate tritium fuel, Tokamak plans to use 'tritium-breeding blankets', in which neutrons generated in deuterium-tritium fusion hit lithium atoms in the blanket and convert them to tritium. The fuel ingredients are continually fed into the plasma as fusion proceeds.

But the crucial innovation, according to the Tokamak team, is the powerful magnets used to generate the fields that confine the plasma. Most tokamaks use either conventional 'supermagnets' made from special metal alloys, or electromagnets made from coils of superconducting materials, which lose all electrical resistance when cooled and can therefore carry large currents. But Tokamak goes one better by using so-called high-temperature ☛

HOW IT WORKS: TOKAMAK ST40

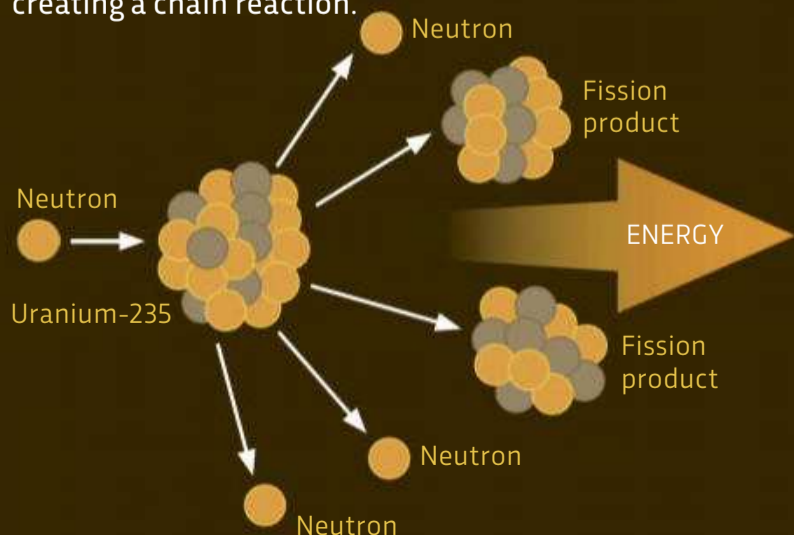
Inside Tokamak's spherical tokamak reactor

- 1 OUTER CASING**
This is made from 30mm-thick stainless steel.
- 2 TOROIDAL FIELD MAGNETS**
These confine the plasma and hold it away from the walls. The plasma particles continuously spiral around the tokamak, following the magnetic field.
- 3 CENTRAL COLUMN**
This contains a solenoid (a coil of wire that generates a magnetic field) that keeps a current flowing through the plasma, helping to hold it stable.
- 4 POLOIDAL FIELD MAGNETS**
These control the shape and position of the plasma.
- 5 PORTS**
These let the scientists monitor the tokamak. The ports also allow for injection of fuel (tritium and deuterium).
- 6 DIVERTOR REGION**
Helium produced in the fusion reaction is skimmed from the edge of the plasma at the top and bottom of the tokamak's inner chamber. Failing to remove this waste would ultimately shut down fusion.
- 7 TORUS OF PLASMA**
This gas of electrically-charged deuterium and tritium atoms will undergo nuclear fusion, with temperatures rising to more than 100 million degrees Celsius (seven times hotter than the centre of the Sun). The heat generated in the reaction is extracted from the tokamak, where it can heat water to drive turbines.



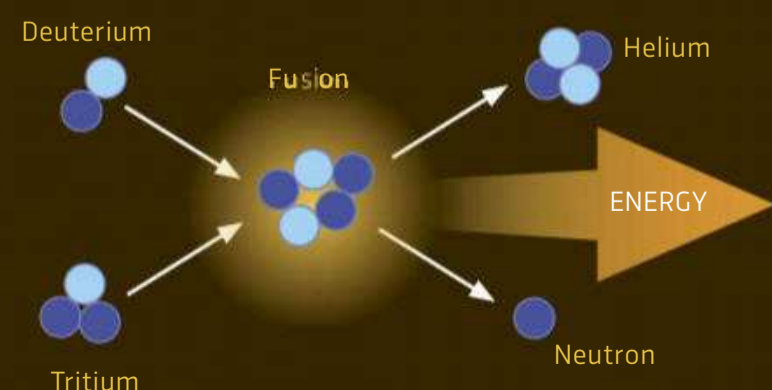
NUCLEAR FISSION

Neutrons are fired at an atomic nucleus such as uranium-235, causing it to split into lighter nuclei and release energy. Neutrons generated in this reaction interact with further heavy nuclei, creating a chain reaction.



NUCLEAR FUSION

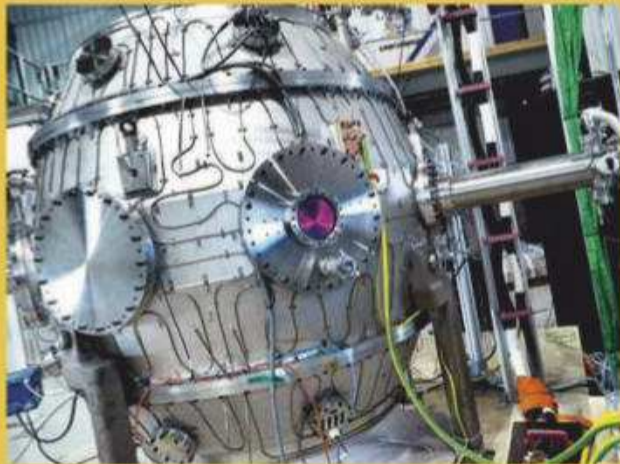
Two or more atomic nuclei are combined to form other nuclei, subatomic particles and energy.



THE FIGHT FOR FUSION

How Tokamak Energy compares to other nuclear fusion projects...

TOKAMAK ENERGY



Location: Milton, Oxfordshire, UK

Date founded: 2009

Type of reactor: Compact spherical tokamak with high-temperature superconducting magnets

Estimated cost: Undisclosed

Current status: Achieved temperatures of 15 million degrees Celsius in 2018

Ultimate goal: To produce commercially viable fusion power by 2030

AGNI ENERGY



Location: Olympia, Washington, USA

Date founded: 2017

Type of reactor: Beam-target

Estimated cost: \$5m (£3.9m approx) for proof of concept; \$150m (£117m approx) for pilot plant

Current status: Seeking a strategic partner

Ultimate goal: Applications in disposal of nuclear waste, and producing fusion energy for eventual scale-up

COMMONWEALTH FUSION SYSTEMS



Location: Cambridge, Massachusetts, USA

Date founded: 2018

Type of reactor: Conventionally shaped, scaled-down tokamak

Estimated cost: Not disclosed

Current status: Demonstrating magnet technology and preparing to build tokamak

Ultimate goal: Demonstrate net fusion energy by 2025, with the first power plant operational in around 2033

● superconductors (HTSs) to create the magnetic fields in their machine. These materials, discovered in the 1980s, can superconduct at higher temperatures than ordinary superconductors and so can be relatively easily cooled using liquid nitrogen. Crucially, they can also carry bigger currents and so generate stronger magnetic fields. Kingham thinks that using HTSs for nuclear fusion magnets could be their ‘killer app’.

“There’s a growing recognition that HTS magnets are a boost to fusion,” says Tokamak’s senior commercial manager Dr Ross Morgan, pointing out that Commonwealth Fusion Systems, a spinout company from the MIT Plasma Science and Fusion Center in the US, also considers this to be the key enabling technology. If it’s to work, the materials

“Unlike fission, fusion can be switched off in an instant. It’s a lot safer”

will need to be made in large quantities, and right now there are few suppliers – one reason why using HTSs is much more feasible for smaller machines. If HTSs became a central component of fusion reactors, they would surely be mass-produced, making them cheaper.

This is only one of the many engineering challenges that must be solved if mini-tokamaks are to become tomorrow’s power sources. Tokamak Energy also places its faith in an unusual tokamak shape: spheres, rather than the usual cylindrical devices favoured by the bigger projects such as ITER and JET. Spherical tokamaks have “significant physics advantages but greater engineering challenges,” says Kingham.

This is a view that’s echoed by Chris Warrick, the communications manager at the UK Atomic Energy Authority (UKAEA) in Culham. “We have known for decades that more compact, ‘spherical’ tokamaks have great potential,” he says. “They are inherently more efficient than conventional tokamaks, requiring less magnetic field to confine the plasma of fuels.” The UKAEA has been developing its own small spherical tokamak, called the Mega Amp Spherical Tokamak (MAST), since the late 1990s. But Warrick adds that they have drawbacks too, especially the challenges of removing the tremendous amount of heat from the reactor, because it is more intensely concentrated in the compact design.

POWERING THE FUTURE

Tokamak Energy is just one of the small players in this game. In the United States alone there has been

GENERAL FUSION



Location: Burnaby, Canada

Date founded: 2002

Type of reactor: Magnetised target

Estimated cost: Several hundred million pounds

Current status: Currently testing components for a demonstration plant

Ultimate goal: Pilot plant within five years, full-scale commercial plant five to seven years later

JET (JOINT EUROPEAN TORUS)



Location: Culham, Oxfordshire, UK

Date founded: Operation began 1983

Type of reactor: Conventional large tokamak

Estimated cost: €200m (£178m approx)

Current status: Holds world record for fusion output power: 16MW in 1997

Ultimate goal: Experimental device to study fusion under conditions approximating those in a commercial power plant (already achieved)

ITER (INTERNATIONAL THERMONUCLEAR EXPERIMENTAL REACTOR)



Location: Cadarache, France

Date founded: Construction began 2013

Type of reactor: Conventional large tokamak

Estimated cost: \$20bn (£15.6bn approx)

Current status: Under construction

Ultimate goal: Deuterium-tritium fusion by 2035, eventually with output power of 500MW

over \$1bn of private venture capital put into fusion projects, and there are now about 25 such companies worldwide. One is AGNI Energy, a Washington-based start-up pursuing an unconventional version of scaled-down fusion in which a beam of high-energy deuterium atoms is fired at a target of lithium and tritium. However, the company's CEO Troy Dana says it is not seeking to use nuclear fusion for power generation. "We have identified commercial applications for our device that do not require net energy gain," he says. The company hopes to have a proof of concept device operating by mid-2019.


Meanwhile, General Fusion, based in Burnaby, Canada, is aiming to develop the world's first commercial fusion power plant using a new technique called 'magnetised target fusion'. This, explains CEO Christofer Mowry, combines aspects of the magnetic confinement of plasma in a tokamak with the alternative approach to fusion called 'inertial confinement', in which lasers are used to cause sudden, high compression of the fuel to trigger fusion. In the General Fusion device it happens in a pulsed manner, rather like the compression cycles of an internal combustion engine. Mowry argues that the bigger fusion projects aren't trying to make cost-effective, commercially viable forms of fusion – which, he says, is precisely why the smaller private enterprises can complement those efforts.

If small-scale commercial nuclear fusion reactors were to become a reality, it wouldn't just transform the way we make energy, it would also alter the whole infrastructure. Unlike fission, fusion can be switched off in an instant. "In a fusion reactor at

any one time, you have only a few seconds' worth of fuel, whereas in a fission reactor you have 25 years' worth," says Kingham. "It's inherently a lot safer."

That means fusion reactors wouldn't need to be far from centres of population or industry. It's possible to imagine towns or companies having their own dedicated machines, making energy generation much more distributed and local.

But will the little guys really achieve where the giants have so far failed? "They [the larger projects] were rather taken aback five years ago when we started to look serious," says Kingham. According to Morgan, the ability of start-ups to build small devices rapidly – in three to four months – is crucial. It means they can learn quickly and build that knowledge into the next generation. In contrast, says Kingham, the large-scale projects "tend to be quite risk-averse and conventional."

Tokamak Energy says that they hope to have a practical device that achieves industrial-scale heat by around 2025, which could become commercialised by 2030. That's ambitious. But as Kingham says, "to make progress, we've got to have bold plans." 

Philip Ball is a science writer and presenter of *Science Stories* on BBC Radio 4. His latest book is *Beyond Weird* (£17.99, Bodley Head).

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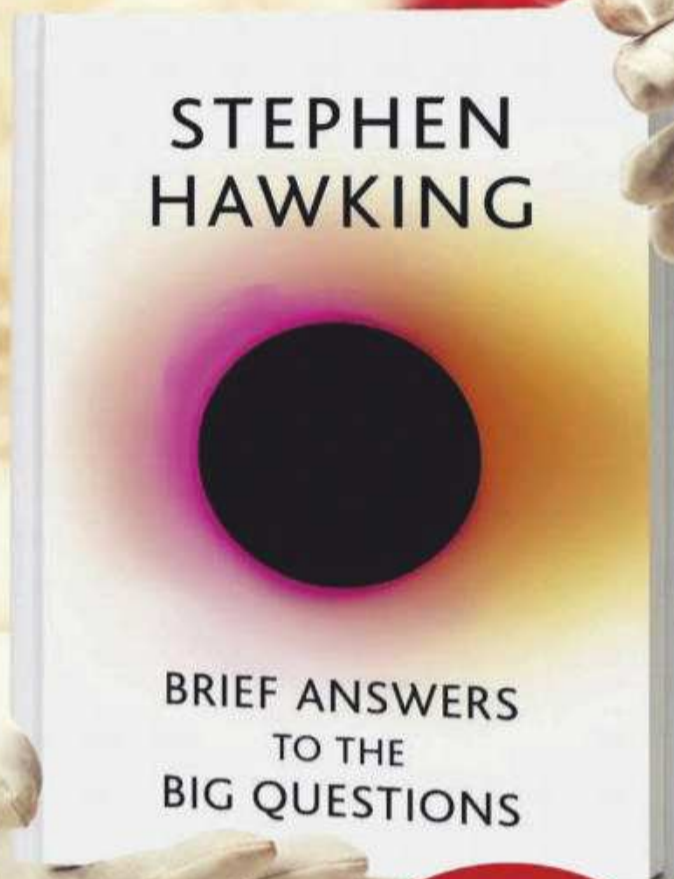
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THE GENETIC HUNT FOR NESSIE

For centuries, many have claimed that a creature lurks in Loch Ness. Now, by seeking out monster DNA from the loch's waters, scientists are going to find out what's down there

WORDS: DR DARREN NAISH

The idea that new, large animal species might be hiding in the world's wilder places has always been one of the most romantic and appealing of scientific concepts. Even today, it remains possible that a few big mammals, fish or reptiles await discovery in the forests of New Guinea or Southeast Asia, or in certain deep-sea basins. But can we take seriously the possibility, endorsed by a handful of die-hards and believers, that Loch Ness, Scotland's largest and most famous lake, is home to a new species of gigantic, dragon-like animal more than 10 metres long?

In May 2018, geneticist Prof Neil Gemmell of the University of Otago, New Zealand, embarked on a project to collect and test genetic traces of animals from the loch, and hoped to resolve the enigma of Loch Ness once and for all. He and his

BELOW: Tales of a monster in Loch Ness have been around for centuries. Prof Neil Gemmell is finding out what lurks in the murky waters once and for all

team were set to use a technique not previously used on the loch's water. They were going to hunt for environmental DNA, or eDNA (see box, right).

ARE YOU THERE, NESSIE?

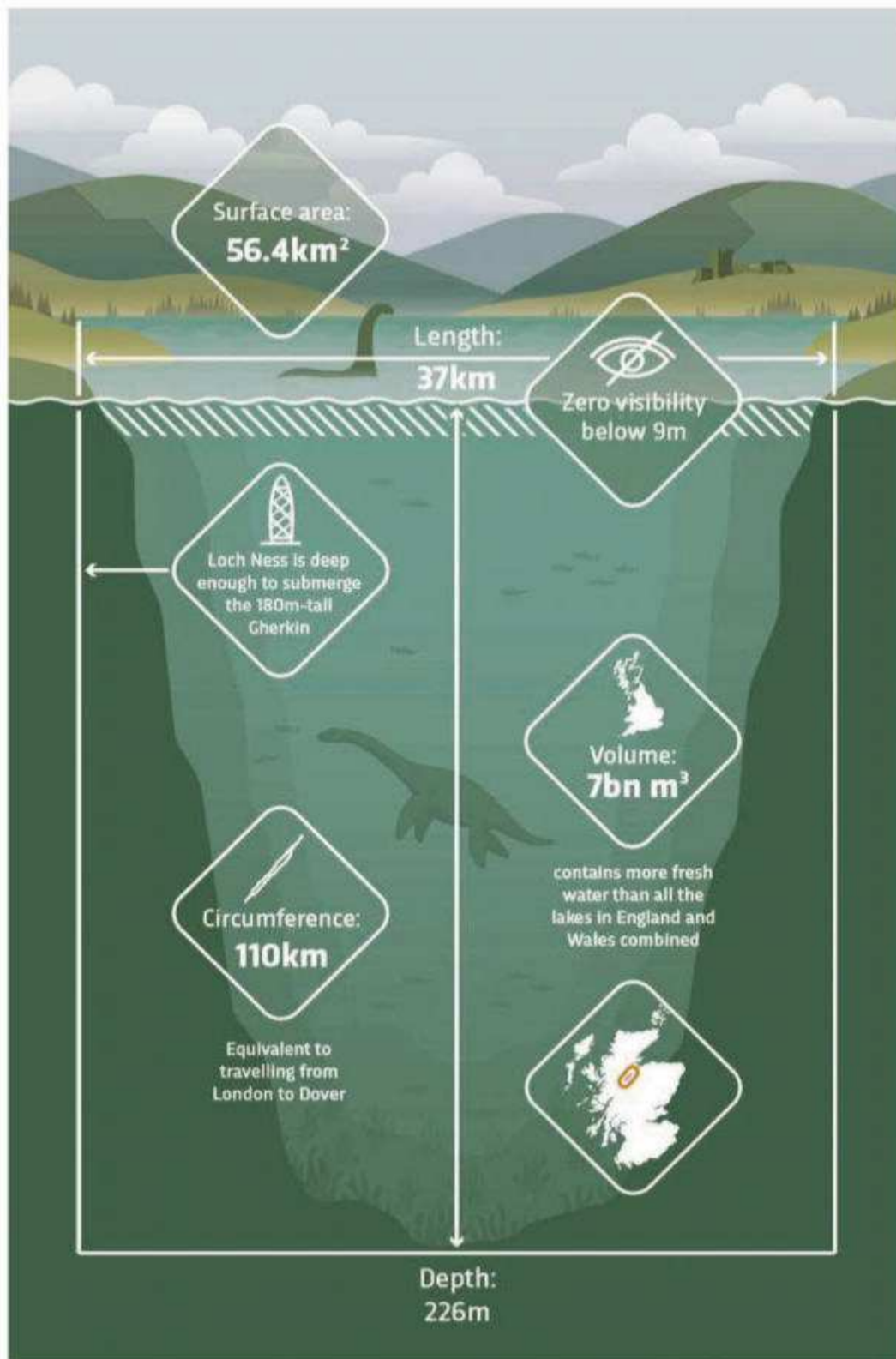
Most scientists do not think there is a monster in the lake. This bold proclamation isn't due to arrogant elitism or an inability or unwillingness to examine the data that exists, but to the fact that the evidence put forward to support Nessie's reality has failed to be persuasive. The photos and films are fakes, hoaxes, or misinterpretations of known objects. Biological evidence that might support the creature's existence – bones, carcasses, feeding signs or droppings – is non-existent. And the large number of eyewitness anecdotes provides nothing robust or consistent. Rather than monsters, there are instead assorted references to all kinds of things seen on the loch, like swimming deer, birds, seals, waves and wakes. Few of these things are familiar to the average loch-side visitor. A psychological phenomenon known as 'expectant attention' is also important in influencing people's experiences at Loch Ness. It explains how people's observations fit an existing expectation, in this case, that they will see a large, water-dwelling monster.

Still, the idea of *something* mysterious in the lake has nonetheless captured the attention of scientists.

“Can we take seriously the possibility that Loch Ness is home to a new animal?”



GETTY X2 ILLUSTRATION BY RAJA LOCKEY



Therefore, the water has been swept by vessels emitting sonar, and its depths have been explored by divers, submersibles and motion-detecting cameras. At least a few authors and scientists have gone on record to state their confident belief in the monster's existence, the data that convinced them later proving inadequate or erroneous. In other words: science has searched for Nessie, and the results have come back negative.

In the 2016 book *Hunting Monsters*, I noted that the ability of scientists to search for and analyse the genetic material that living things leave in their environment – so-called environmental DNA, or eDNA – might provide the ultimate arbiter of the presence or absence of a mystery creature in the loch. Gemmell was inspired. “I was thinking how we might use eDNA to search for and identify creatures that live in areas hard to investigate using traditional approaches, such as deep oceans and subterranean water systems. Loch Ness seemed a perfect fit for that sort of project,” he says. “I’m not a Nessie believer, but I’m open to the idea that I might be wrong. This project is about understanding the

RIGHT: Most eDNA found so far belongs to living species already known to science. However, some eDNA has been found from extinct animals, like mammoths and giant sloths. This proves that eDNA can last for thousands of years in the right conditions

WHAT IS eDNA?

DNA extracted from an organism can reveal a great deal about its relatedness to other living things, both in the small-scale sense of how it compares with other populations within its species, and in the broader sense of where it fits within the tree of life.

But if it only takes a tiny sample of organic tissue – a single skin or gut cell, for example – for DNA to be extracted, then could DNA-retrieval techniques be sophisticated enough for us to collect DNA that living things leave in their environments, via their shed cells, urine and faeces? The answer is yes. In a series of studies that first appeared in print during the 1990s, ecologists and geneticists worldwide have shown how the presence and identity of organisms in

an area can be extracted from soil, groundwater, ice, freshwater and seawater via so-called environmental DNA or eDNA.

By collecting water from Loch Ness, scientist Prof Neil Gemmell and his team hope that they have obtained eDNA from the loch environment. They have also taken samples from nearby lochs to analyse their eDNA too. Back in the laboratory, the samples will be analysed, and any eDNA will be identified and extracted. The samples are then profiled and compared to those already in genetic databanks. Many species already known to be present in the loch will be identified in this way. The hope is that species new to the area, and perhaps even new to science, will be discovered as well.



“We could gain important information on valuable, rare or sensitive species”

● biodiversity of Loch Ness, with the added bonus being that we might find evidence of something new that may explain the monster legend.” According to Gemmell, the study could also have benefits for our understanding of the health of Loch Ness and its future management. He’s currently awaiting the results of the survey.

SPECIES SEARCH

The study of eDNA has proved an invaluable tool to biologists ever since it was devised in the 1990s. It has been used to examine the distribution of species no longer present in an area, but whose genetic traces are still preserved in sediment. It has also proved crucial in tracking the spread of invasive species. Asian grass carp in the North American Great Lakes and the New Zealand mud snail in the western USA, to use just two examples, have both had their progress monitored via eDNA.

eDNA studies have also been used in the search for species that are rarely seen by people and, in some cases, not seen at all. A 2012 study of seawater from the Baltic confirmed the presence of long-finned pilot whales in the area, a species not seen by people during the period covered by the study and generally thought to be an extremely rare visitor there. More remarkable is a 2018 study concerning eDNA collected from the marine

eDNA TO THE RESCUE!

As well as helping us discover the truth about Nessie, eDNA has many other useful applications...

NEWT RESCUE

Great crested newts are protected by European law. When development work that could affect freshwater bodies is planned, some ecologists in the UK use eDNA techniques to check for the presence of the amphibians before any building takes place.

SAVE THE WHALE

Scientists at Oregon State University want to use eDNA to investigate beaked whales. This elusive group of 23 species – some of which have never been seen alive – are tough to locate, which makes eDNA a handy tool to help us learn about these mysterious animals.

SHARK CONSERVATION

Sharks are a priority in ocean conservation. Yet as they have huge ranges, they can be difficult to monitor. By taking water samples from the Coral Sea and the Caribbean Sea, a research team identified the distributions of at least 21 species of shark, and proposed that eDNA could help generate conservation strategies.

FISH FARMING

Every year, the aquaculture industry loses huge numbers of fish to disease. A team at James Cook University has used eDNA to detect bacteria and parasites in the water of farms, before any of the fish get ill. This will help farmers to kill off any bugs before they become a problem.

WHAT COULD NESSIE BE?

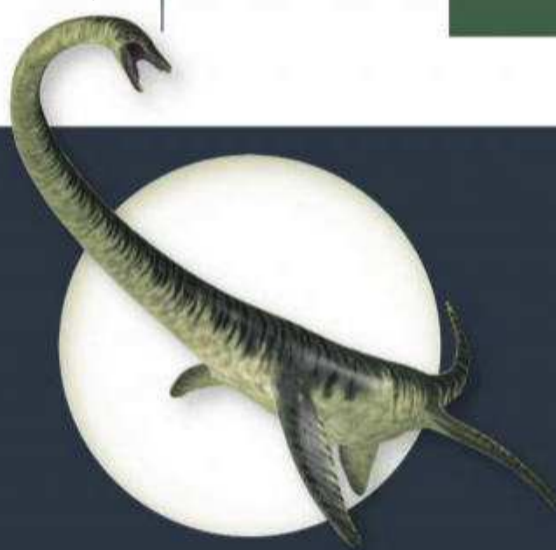
This eDNA study will be the first to qualify if there is an unexpected creature in Loch Ness. Here are the suspects of what Nessie might be...

A PLESIOSAUR?

A long-extinct group of aquatic reptiles – the plesiosaurs – have frequently been mentioned in connection with Loch Ness, mostly because Nessie is often said to have a long neck, much like a plesiosaur. But the fossil record gives no indication that plesiosaurs have survived any more recently than 66 million years ago.

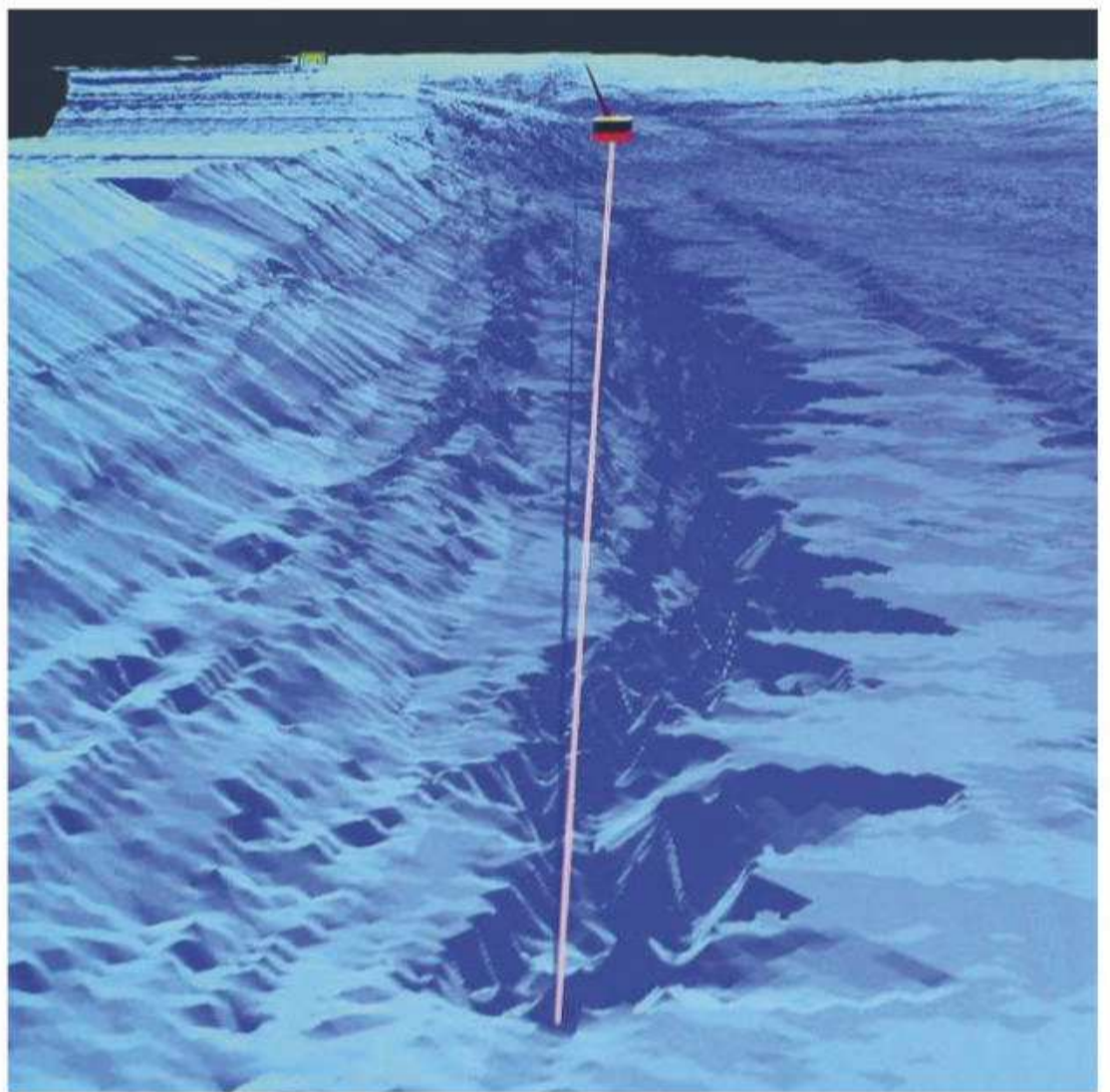
A GIANT EEL?

Several monster experts have proposed that Nessie might be an eel that has grown to a size about 10 times bigger than the norm for its species, perhaps because it has been living there for decades or centuries. There are no good indications, however, that eels really can keep growing in this way.




waters of the New Caledonian archipelago in the southwest Pacific. This revealed the presence of six shark species that were not picked up at all via more conventional sampling techniques, like long-term observation and the use of baited locations set with automatic cameras.

It's doubtful that any of the scientists involved in these various eDNA projects ever considered how applicable this work might be to the search for lake monsters, but it's with this record of eDNA-based successes in mind that Gemmell announced his plans to collect and analyse eDNA from Loch Ness. An eDNA census of the loch could potentially reveal the presence of a large animal matching the 'monster' imagined by witnesses and Nessie-hunters. But it would also provide a list of the many additional species living there. Given the success of eDNA in documenting the presence of animals, it is quite plausible that an eDNA study could document fish, molluscs or other species not currently known to be living in the loch. Invasive species could be among them – organisms we urgently need to keep track of. And we could also gain important information on the whereabouts and movements of economically valuable, rare or environmentally sensitive species, like various members of the salmon family, or the European sturgeon. In short, the scientific pay-off for the study will be substantial, whether a monster is discovered or not. "We figured at the outset that we would likely describe the biodiversity of the loch. I anticipate finding evidence of all the fish species previously reported, plus perhaps some others that we think may be present," Gemmell says. "We also think we might find new forms of bacteria and other life, particularly in samples from around methane seeps in the loch and the fridge-like depths 200m down."



ABOVE: Sonar reading of Loch Ness, taken by a tour boat captain, revealed a deeper section, which some people think could be a hiding place for Nessie

Nobody really expects to discover evidence for a creature that might be regarded as similar to the 'Loch Ness Monster' of popular lore. But much remains to be learnt about the biology and ecology of Loch Ness and its surrounding lochs and lakes. If eDNA and questions about a monster help us to investigate this subject and learn more about the natural world and how it functions, then this has proved a most worthwhile endeavour. 

Dr Darren Naish is a palaeontologist and science writer. He is the author of a number of books on cryptozoology, including *Hunting Monsters: Cryptozoology And The Reality Behind The Myths*. He tweets from @TetZoo.



A STURGEON?

Sturgeons are slow-moving, bottom-feeding fish that have a row of armour plates along the spine, a pointed nose and a sucker-like mouth. They can be up to seven metres long, and are known to move in and out of lakes and rivers according to the season. Sturgeons could explain some Nessie reports.



SOME FLOATING VEGETATION?

Biologist Dr Denys Tucker argued that rotting masses of vegetation might burst to the loch's surface and then be propelled along at speed by the gases of decomposition. Sightings of such events, he argued, might explain monster reports. However, scarcely any monster reports describe objects that match his idea.



WEIRD SEISMIC ACTIVITY?

Loch Ness is located within a geological fault known as the Great Glen, and certain sections of it are still seismically active. Perhaps minor earth tremors are responsible for weird shapes in the water and releases of bubbles that witnesses have interpreted as sightings of monsters.

ADVENT GIFT GUIDE



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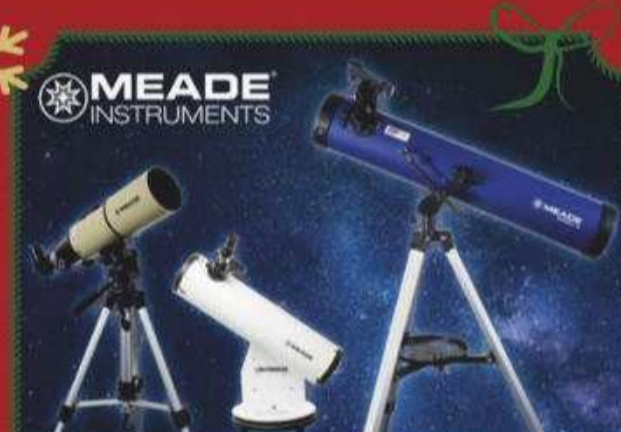
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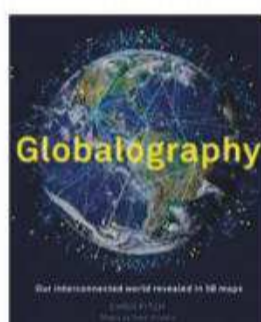
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THE MAGIC HOUR

Dynasties, a new series narrated by David Attenborough, reveals the power struggles within animal groups. Episode producer **NICK LYON** tells **HELEN GLENNY** how 18 months of sleepless nights, undocumented behaviours and Shakespearean drama became an unforgettable 60 minutes of TV

What's the painted wolves episode about?

We were looking at a big family that would go through a change of leadership during filming. Tait is our central character. She's the old matriarch and mother to two neighbouring alphas, Black-Tip and Janet. Black-Tip's pack had grown very big, and there wasn't really enough space, so her only option was to turn on her mother and take her throne. It's a Shakespearian tale of a mother defending herself against her daughter. We were pretty certain that Tait would not survive the film, but we did not know how things were going to pan out, and what happened was unexpected.

How did you capture all of that?

We did 11 trips out to Zimbabwe,

filming for 585 days in total in Mana Pools National Park. Usually on these filming shoots you have quite a steep learning curve, so you find your rate of acquisition of useful shots peaks towards the end, and then you go to a different location and a new story and you have to start that learning curve again. The brilliant thing about this is that we could build on that learning curve every time we came back, so we weren't always starting from square one.

Were you always confident you'd get the footage you needed?

There were times when we thought we weren't going to pull this off. My second shoot on *Dynasties* was incredibly tough. It was one-month long, we had

16-hour days every day, and we spent a total of two hours with our subjects.

Over the course of the whole month?!

Yeah. It's funny, because it's tiring when you're filming, but when you find the animals, it's enough to keep you going. You can live off adrenaline and fumes for a while, even if you're kind of empty in the tank.

But when you don't find them, you're getting up at 3am knowing that you're going to be driving all day looking for tracks. So you have to pretend to yourself that you'll find them, even though you know you didn't see them yesterday or the day before. That's when it can get gruelling.

We pushed through that, but the third shoot was by no means a certainty. Tait ►



● was unusual in that she denned in the same three dens in the same order, so we thought we could find her. But we hadn't counted on Black-Tip coming in and booting her off her territory.

So we didn't know where Tait was, and we issued park-wide searches. I think our trackers walked every corner of the park for three or four weeks solid to find Tait's den. I think it was two days before the shoot that we finally got the call that they'd found the dens. Otherwise, we would have had to pull the cord and that might have been the show abandoned.

Were the painted wolves comfortable around you?

Our guide, Nick Murray, has known Tait her whole life. She's incredibly trusting of him. The fact that it was Nick who introduced us to Tait transferred her trust for Nick to us. Over time the animals just got to trust us more and more, and we were able to introduce new bits of kit that we didn't think we'd be able to use. If we'd just been there for three weeks, I wouldn't have put a drone up, but by the ninth shoot, they were so used to anything we did that we showed them the drone, put it in the air, and they were super chilled. They didn't even look at it.

How long did that take?

They relaxed with us quickly, but there was a marked shift on that third shoot

when Tait had had her puppies, and they were happy with us filming next to the den. Every morning and evening they'd go out hunting, and they'd always leave a babysitter by the den, and one morning Tait joined the hunt, and I was thinking, "Oh, I wonder who's she's left to babysit?" I was looking around and I couldn't see anyone, but I thought they were just hidden back in the bushes.

I was fiddling with a remote camera while the adults were away, and the puppies popped out of the den, so I looked up to see where the babysitter was, because their job is to put them back to bed. But no one was there, and it dawned on me that Tait had left us as the babysitters! That seemed like a big shift, and after that there was no looking back. The relationship just got better and better, it got to the point where I could sit in the water, filming and photographing, with them racing around me on all sides. It's those sort of experiences that you can only get by spending long periods of time with individual animals.

Did you see any behaviour you didn't expect?

Yes, lots of things. Black-Tip's pack started to hunt baboons about six months into filming, which is highly unusual behaviour. Even leopards, who people often associate as being baboon hunters, actively avoid hunting baboons statistically. They will occasionally get

them, but they much prefer impala.

Black-Tip's pack did a total shift in behaviour where about 50 per cent of their diet moved to baboons in the dry season, and we were there to capture it on camera. We got so many records of it that we're able to assist in publishing a new scientific paper on baboon hunting in painted wolves.

Why did they make that change?

Well, this is my guess. Mana Pools has many elephants and lots of low, wet areas. There are these really massive tracks of elephant footprints, like craters, and once it gets dry, those soft footprints in the mud become baked hard. We've clocked the painted wolves at 70 kilometres per hour chasing impala, so when they hit those patches of elephant footprints, we've seen legs being broken, frequent strains, there's always at least one animal limping in the pack. So while baboons are dangerous in themselves, the risk of picking up an injury from hunting impala in the dry season seemed to be higher than taking on these big baboons.

Black-Tip's pack was much bigger than normal – up to 30 animals. Today it's rare to see packs of that size, and it allows them to hunt differently. I think when you've got so many animals, it's easier to distract big, male baboons.

How did you film the packs hunting?

We had plenty of fancy kit for this, but

MANA POOLS NATIONAL PARK NORTHERN ZIMBABWE

This UNESCO World Heritage site spans over 2,000km near Zimbabwe's northern border

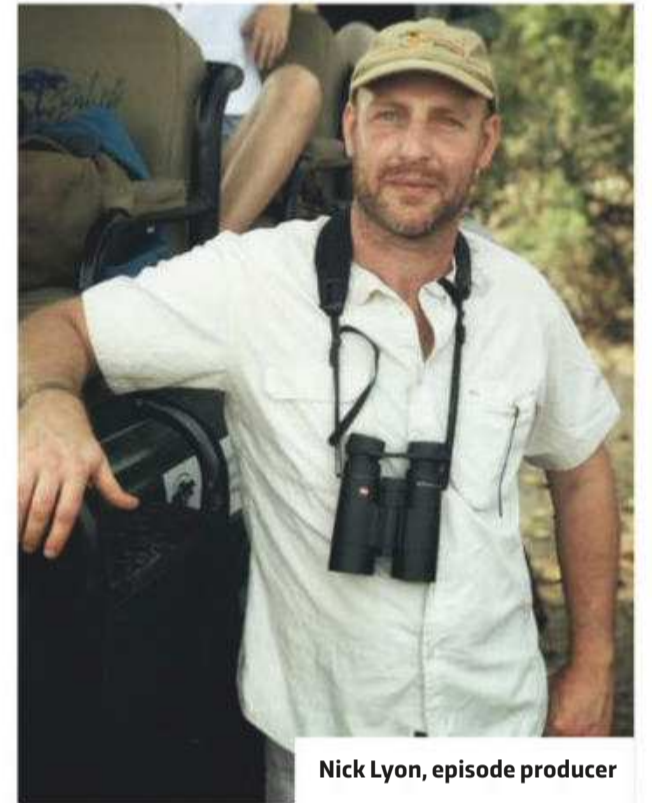
Mana means 'four' in Shona, a local language, referring to four permanent lakes formed by the Zambezi river. In the dry season, the area attracts huge concentrations of wildlife, including hyenas, elephants, lions and buffalo.

"Of all the places in the world I've worked, this is the most beautiful. It's got the Zambezi River on its northern border, and the backdrop is the Zambian Mountains. We saw about 10 different interactions between species, which is a testament to how diverse Mana Pools is," says producer Nick Lyon.



Painted wolves, also called African wild dogs or painted dogs, are found in pockets of sub-Saharan Africa. They are endangered, with threats that include habitat loss, human persecution, and diseases from domestic dogs

“We wanted to give people a fresh look at this species”



Nick Lyon, episode producer

most of the time, we’re filming off a tripod, which isn’t moving. You have to really be able to get into the heads of the animals, because if you just follow them round, you end up shooting film of their bums. So, we’re constantly having to predict which way they’re going to go. It got to the point where we could drive five kilometres away, and sure enough, 15 minutes later we’d have them barrelling straight down the lens, and often they’d run either side of us.

It’s a lot of gambling, but you have to take that high-risk approach to get those better shots. We needed faces and camera action.

What do you think the painted wolves thought you were doing?

I really couldn’t say. I think they must have thought it was weird that we kept following them and not taking their food. Hyenas are always nabbing their food, whereas we were just following.

Do you think your presence ever changed their behaviour?

We need to film natural behaviour, so the last thing we want is to interfere with what they’re trying to do. When

you’ve got mortal danger, you don’t want an animal looking at the camera crew and going, “What are those people doing?” We built the level of trust up so much that when things did get hairy, they would never worry about where we were, because we didn’t want to interfere with their ability to defend themselves or the puppies.

We were also careful that we weren’t habituating them to people. They habituated to us as individuals, and we could get as close as we liked, but we never wanted the tourists in Mana Pools to see what we were doing and think it would be acceptable for them to try and do it, so we’d back off the animals massively if we saw tourists about.

Were you using any new filming technology on the shoot?

I wouldn’t say it’s radically new, but we had a new camera sensor that was a lot more sensitive, so I would say without it, 80 per cent of our footage would have been unachievable because of the animal’s patterns of behaviour. They often didn’t even get up until sunset, and our normal cameras really struggle with light as soon as it gets to that time.

There’s an interaction with honey badgers that looks like daylight, but it actually happened after sunset. With our previous cameras, we would have missed that whole encounter. These cameras were delivering such good images that there was a period of time of about half an hour after sunset where the cameras were actually seeing better than our eyes. This made all the difference, particularly for this species.

Are painted wolves under pressure from humans?

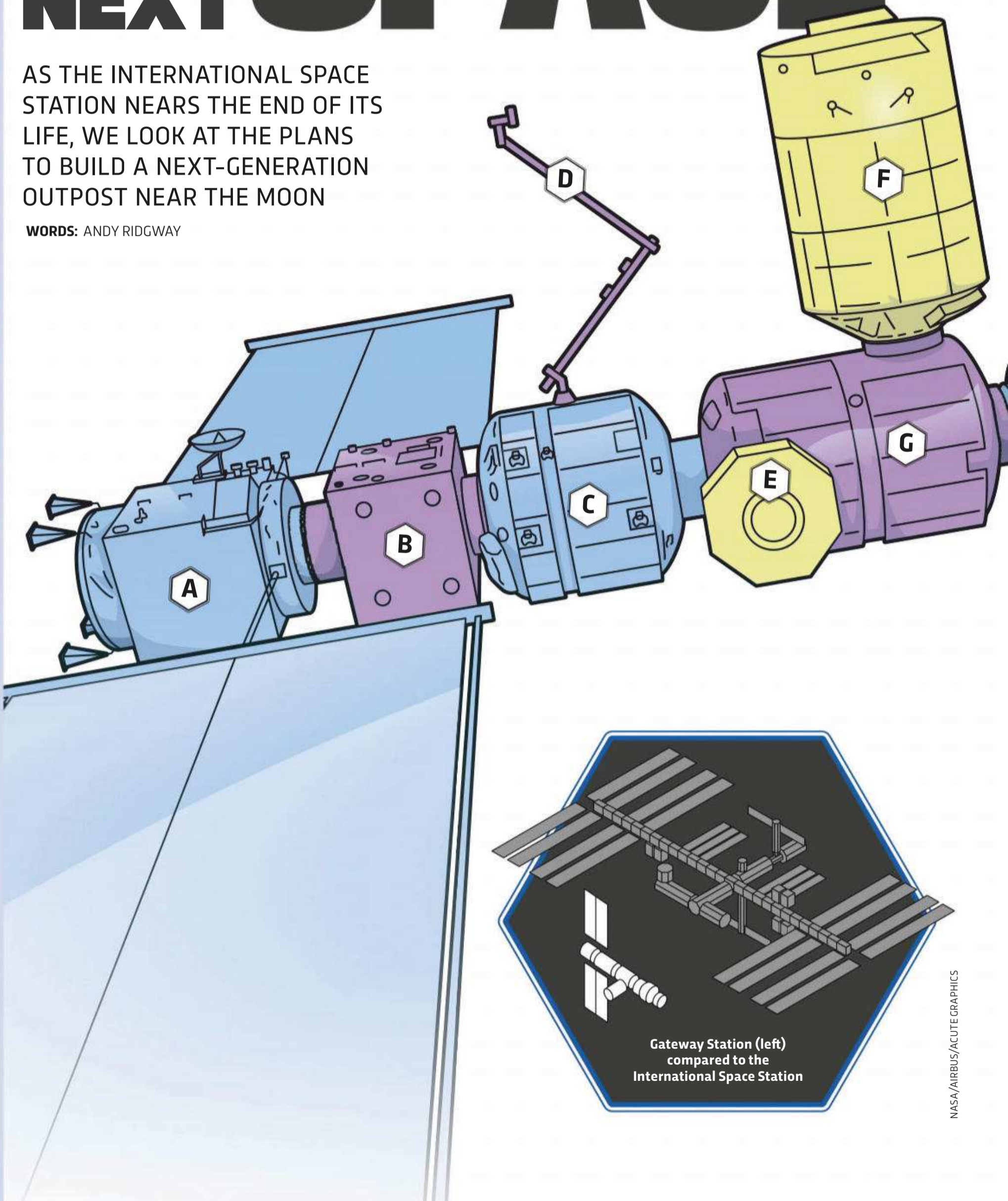
Yeah, there were only about 6,600 wolves when we were filming, and actually I’d be surprised if there are that many now. The biggest problem for all of them is space. Painted wolves are probably the first thing to disappear when land starts to get encroached upon, and they need big home ranges. I think the subtext of this series is animals are running out of space in this world, and we need to be thinking about that seriously.

We wanted to give people a fresh look at this species, and hope that we did our little part to help them have a future, because they are disappearing fast. **F**

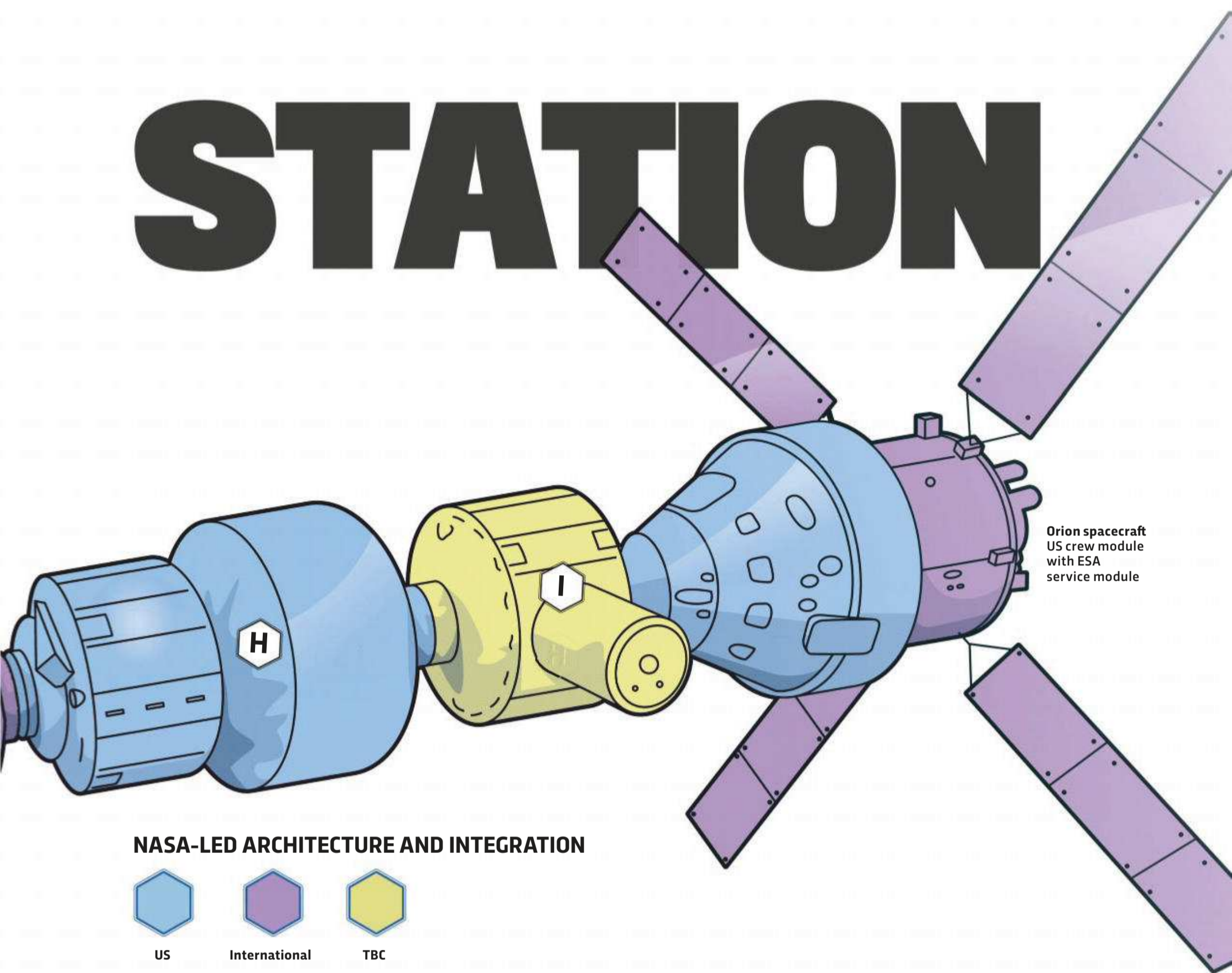
THE NEXT SPACE

AS THE INTERNATIONAL SPACE STATION NEARS THE END OF ITS LIFE, WE LOOK AT THE PLANS TO BUILD A NEXT-GENERATION OUTPOST NEAR THE MOON

WORDS: ANDY RIDGWAY



STATION



Orion spacecraft
US crew module
with ESA
service module

NASA-LED ARCHITECTURE AND INTEGRATION



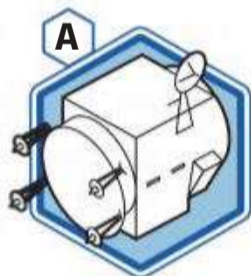
US



International



TBC



Power and Propulsion Element
Provides power, communications, altitude control, orbit control and transfer capabilities for Gateway.



Esprit
The ability to refuel the tanks of docked spacecraft may be tested on this module, as Gateway could act as a refuelling station for craft travelling further into deep space.



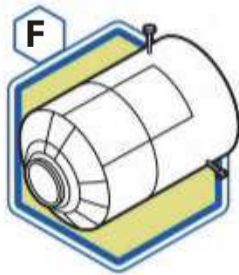
Utilization Element
Small pressurised area for additional storage or habitation.



Robotic arm
Mechanical arm to berth and inspect vehicles, and install science payloads.



Sample Return Vehicle
A robotic vehicle capable of delivering small samples or payloads from the lunar surface to Gateway.



Logistics and Utilization
Cargo deliveries of consumables and equipment. Modules may also double as additional space for astronauts or science experiments.



Habitation Modules
It's currently anticipated that the four astronauts will live in two almost identical modules. Docking ports on the modules will allow them to receive spacecraft from Earth as well as lunar landers. Space junk wouldn't pose such a problem in lunar orbit as it does on the ISS, but protection would still be needed against meteoroids.



Airlock
Enables spacewalks, potential to accommodate docking elements.

A

distance of 410,000km. That's how far away astronauts will be when they're living aboard a new space station that's set to be built in orbit around the Moon. To put it in context, you could fit 30 Earth-sized planets across that distance. Currently

in development, the 'Lunar Orbital Platform-Gateway' will take humans further from Earth than ever before. Known as Gateway for short, and previously named Deep Space Gateway, the space station is being developed by NASA and other space agencies, including the European Space Agency (ESA) and Russia's Roscosmos. It will be a replacement for the International Space Station (ISS), which this month celebrates its 20th birthday. While the fate of the ISS hangs in the balance, one thing is certain – the White House has asked NASA to stop funding the ISS in 2025. Instead, the Trump administration wants the space agency to focus its efforts on returning to the Moon and then to Mars. And that's where Gateway comes in.

"Gateway has been developed to take humans beyond low Earth orbit and out into the cosmos," says Dr James Carpenter, an ESA scientist working on the new space station. "The idea is that it provides an infrastructure for future exploration, and somewhere we can learn how to live and work in deep space." Whereas the ISS flies in low Earth orbit, just 400km (250 miles) above our heads, Gateway will be hundreds of thousands of kilometres away.

Gateway will make the surface of the Moon one short hop for astronauts, allowing them to explore like never before, and creating a new generation of Moonwalkers in the process. It'll also enable a new wave of science experiments to probe some of the mysteries of deep space. In the longer term, it is hoped that Gateway will act as a service station for spacecraft taking astronauts to Mars and beyond. But building a space station way out in lunar orbit is strewn with challenges. How do you lug tonnes of hardware all the way out to the Moon? How do you keep astronauts safe? Unlike those on the ISS, the astronauts aboard Gateway won't be shielded from cosmic radiation by Earth's magnetic field. And they can't just be whisked back home if something goes wrong. Aboard the ISS, they can return in hours. The journey between Earth and the Moon takes days.

SIZE MATTERS

Gateway will be different from the ISS. For starters, it will be much smaller. At 109m long and 73m wide, the ISS is slightly larger than an American football field. The main body of Gateway will be 30-35m long and 5m



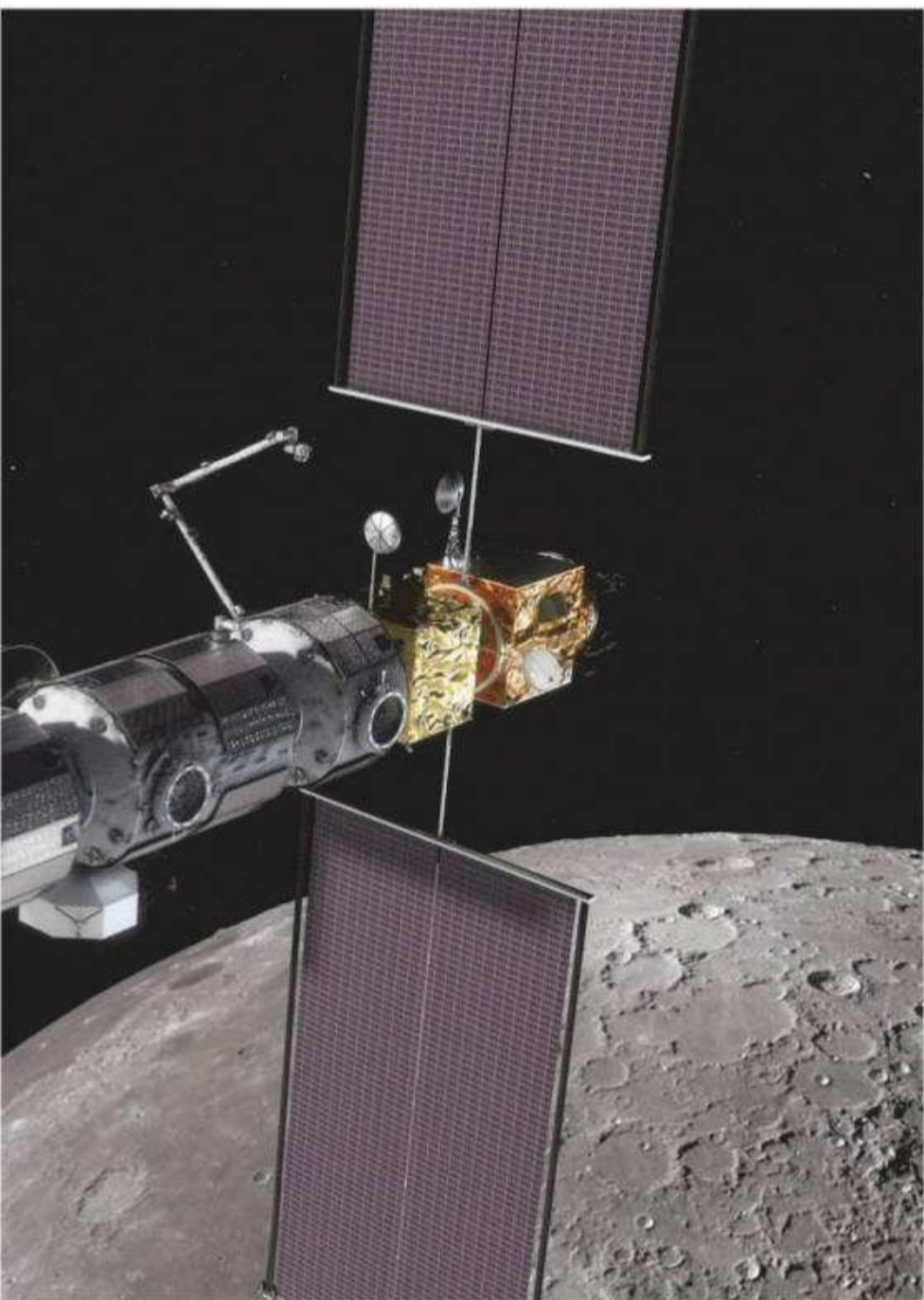
ABOVE: The Gateway station, as visualised here, will allow us to learn more about exploring and travelling in deep space

RIGHT: When NASA's Space Launch System, as seen in this illustration, is completed, it will be the world's most powerful rocket and will be used for deliveries to Gateway

wide. For comparison, a typical London Underground carriage is around 17m long and 3m wide. And while the ISS is occupied by at least three astronauts 365 days a year, Gateway will be occupied by four crewmembers, but only for 30 days a year, due to the cost of getting astronauts there. The rest of the time, it won't have a soul on board.

Those lucky enough to make it to Gateway will be in for one heck of a ride. On the space station's most likely path around the Moon, astronauts will pass within 3,200km of the lunar surface. "Once a week, you would see the Moon very large beneath you," says Jim Clark, an aerospace engineering PhD student, who works in a lab that conducts research on the design and controls of Gateway. "It would fill the view out of the window." At the furthest point on its orbit, however, Gateway will be about 70,000km from the Moon and 410,000km from Earth. The two celestial bodies will be nothing but distant spheres: unprecedented isolation.

This far away, communications will be a huge challenge. If the same radio technology was used aboard Gateway as is used on the ISS, the data rate would be 1/160,000th that on the ISS. "This would only be useful for minimal status signals and possibly voice ►



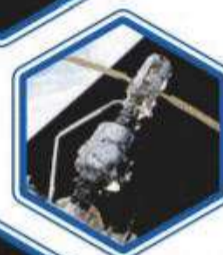
A BRIEF HISTORY OF THE ISS

10 MILESTONES FROM THE SPACE STATION'S 20 YEARS



20 November 1998

The first ISS module, Zarya, is launched on a Russian Proton rocket from Baikonur Cosmodrome in Kazakhstan.



4 December 1998

Unity, the first US-built component of the ISS, is launched aboard the Space Shuttle Endeavour.



7 December 1998

Astronauts Jerry Ross and James Newman make the first spacewalk outside the ISS, connecting computer and electrical cables between the Unity and Zarya modules.



2 November 2000

Astronaut Bill Shepherd and cosmonauts Yuri Gidzenko and Sergei Krikalev become the first crew to stay on board. The ISS has been continuously occupied ever since.



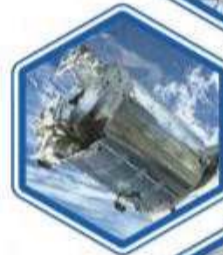
10 February 2001

The Destiny laboratory module is attached to the rest of the station and continues to be the primary US science lab to this day.



10 March 2001

Astronaut Susan Helms becomes the first female crewmember. Peggy Whitson becomes the first female commander of the ISS in October 2007.



11 February 2008

The European Space Agency's Columbus module is attached to the station. Costing €1.4bn, this is the first permanent European research lab in space.



12 May 2013

Commander Chris Hadfield gives a rendition of David Bowie's *Space Oddity* during his final stay on the ISS, turning him into a worldwide celebrity.



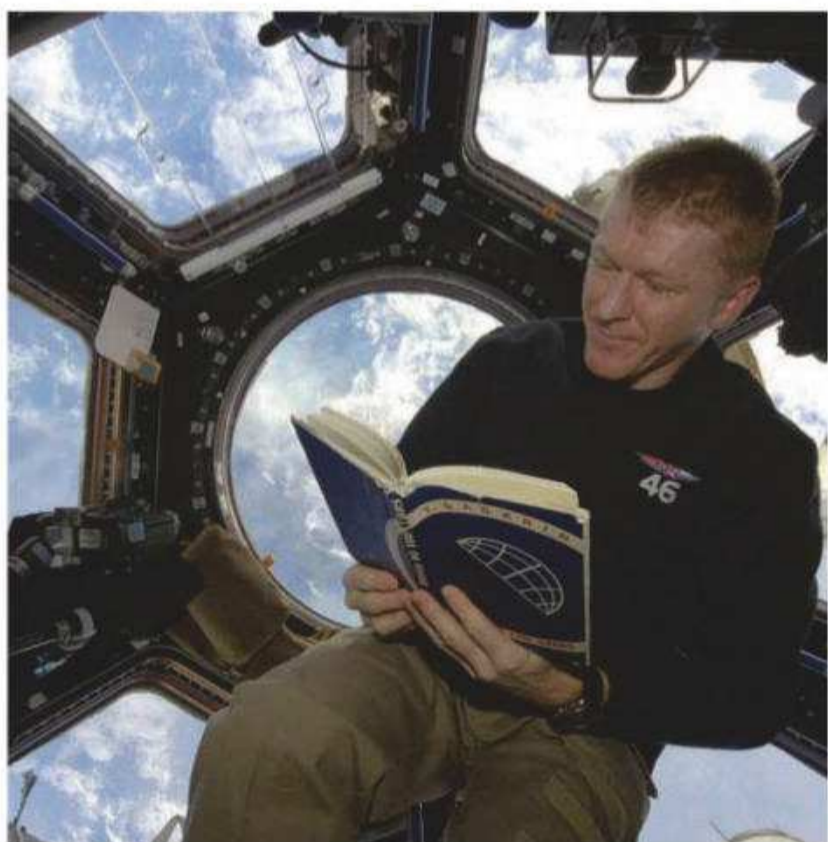
15 December 2015

Major Tim Peake becomes the first British astronaut to board the ISS, staying for six months.



2 March 2016

Astronaut Scott Kelly and cosmonaut Mikhail Kornienko return to Earth after a 340-day stay, the longest in the space station's history.



► communication,” says Clark. If the astronauts wanted to transfer scientific data to Earth-bound researchers, or carry out video calls with their loved ones, they’d need a much speedier connection. One option is to move from radio to laser communication – something that NASA plans to trial on a commercial satellite next year.

MULTI-PURPOSE VEHICLE

A key feature of Gateway is that it won’t be stuck in one orbit: it’s been designed so that it can fly into different ones, depending on its mission. In other words, it’s a cross between a spacecraft and a space station.

Whereas the ISS uses chemical thrusters to give it the occasional boosts needed to keep it in orbit, Gateway will shift between orbits by using solar electric propulsion, a technology that uses energy from the Sun to power fuel-efficient thrusters. Other orbits proposed for Gateway include a tight orbit close to the lunar surface, and a larger orbit some 1.5 million kilometres out into space.

Gateway’s propulsion system will be the first of the station’s modules to be launched into space – as soon as 2022. NASA is expected to award the contract for this element to a private company next March. All of the station’s other components will be lifted into space by NASA’s new load-lugging rocket, the Space Launch System (SLS), capable of taking over 100 tonnes of hardware into low Earth orbit, including the Orion spacecraft (also currently in development). Once the Gateway modules and Orion are in space, Orion will transport the modules out to lunar orbit so that they can be linked together.

It’s also in Orion that astronauts will reach Gateway – a journey that’s likely to take around three days. Once they’re there, one of the biggest questions is how to keep them safe in the event of an emergency. The main solution will be to replicate essential technology in different parts of the space station, so the astronauts



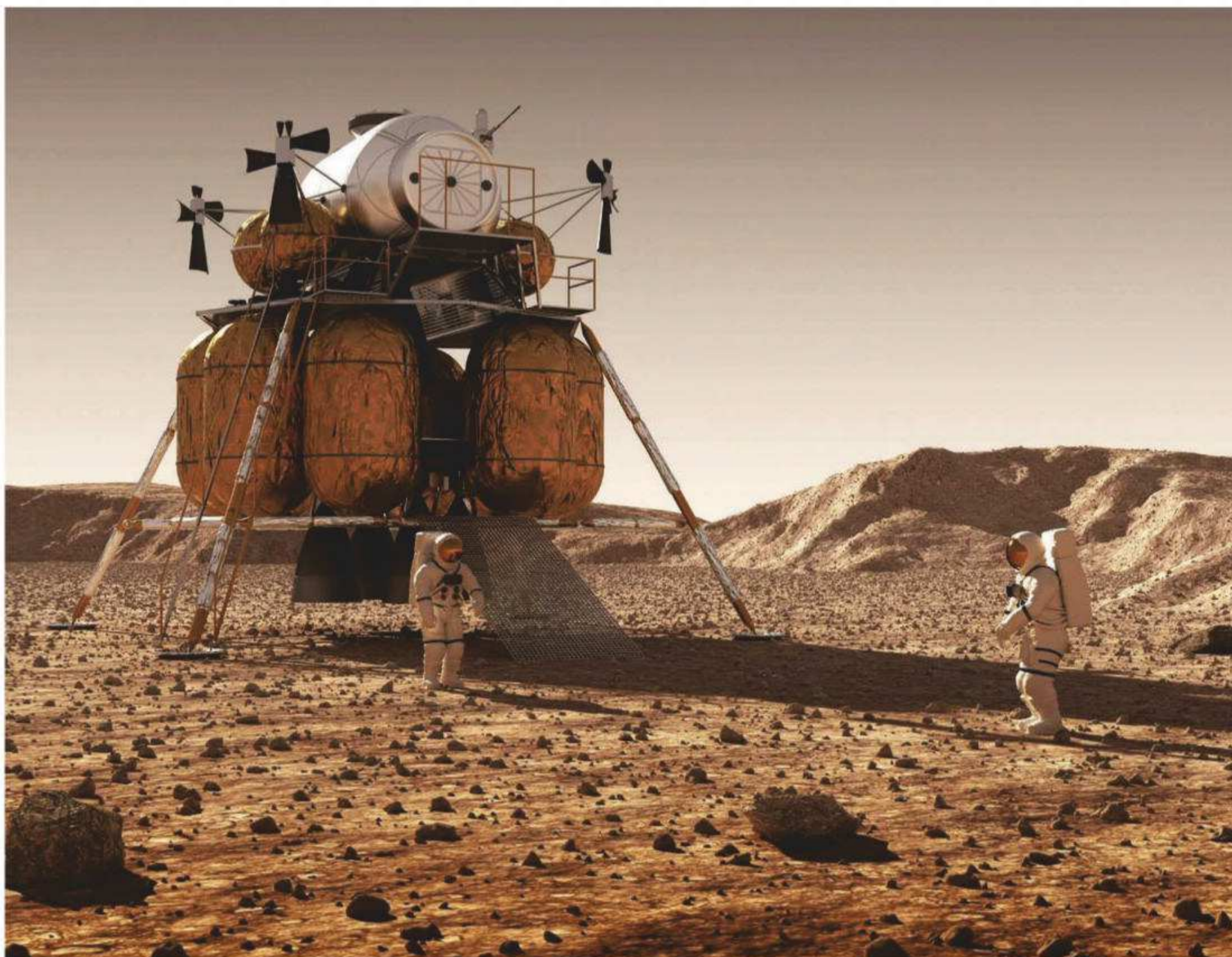
ABOVE LEFT:
Major Tim
Peake takes
some time out
aboard the ISS

ABOVE:
Testing of
Orion, which is
the spacecraft
that will take
astronauts to
Gateway

can move to another area if one piece of equipment gets damaged or broken. “So if that module has to be chopped off, don’t worry you have computer power on the other side, you have propulsion on the other side,” says Prof Mitchell Walker, an aerospace engineer at Georgia Tech College of Engineering in Atlanta, who’s not involved in the project. “You always want to be in a position where there is a duplicate of everything.” This would make a situation that requires an evacuation of the whole space station much less likely.

MOON LAB

Then there’s the question of cosmic radiation in deep space. “The entire space station could be heavily armoured against radiation, but that carries a cost in fuel to get it there,” says Clark. “So they may choose to make just one section heavily armoured, to act as a storm shelter.” Thicker metal walls would act as a radiation barrier in this shelter. Astronauts might sleep in it overnight, or take refuge during periods of intense radiation, such as during a solar flare.



Studying this radiation will be a research priority on board Gateway, as it's something we know surprisingly little about. "We know that cosmic radiation consists of solar wind, galactic cosmic rays and solar flares, but we don't know the levels of each, and whether there are certain patterns in this radiation or whether it's random," says Dr Jennifer Ngo-Anh, who coordinates human, biological and physical science research for ESA and has been tasked with shaping Gateway's research projects. What Gateway tells us about cosmic radiation will help scientists develop the protection needed for a trip to Mars and back. "If we want to do human exploration in deep space, radiation is currently one of the showstoppers," says Ngo-Anh.

Both NASA and ESA have been asking scientists what kinds of experiments they'd like to run aboard Gateway. The Moon is a key target, especially since the confirmation of water ice on the lunar surface earlier this year. A big question is the exact origin of this water, as well as other 'volatiles' (substances with low boiling points) on the Moon, such as hydrogen sulphide and sulphur

"GATEWAY WILL ACT AS A TEST BED FOR THE TECH REQUIRED FOR MISSIONS TO MARS"

ABOVE: In time, it is hoped that Gateway could be used as a stop on the way to Mars

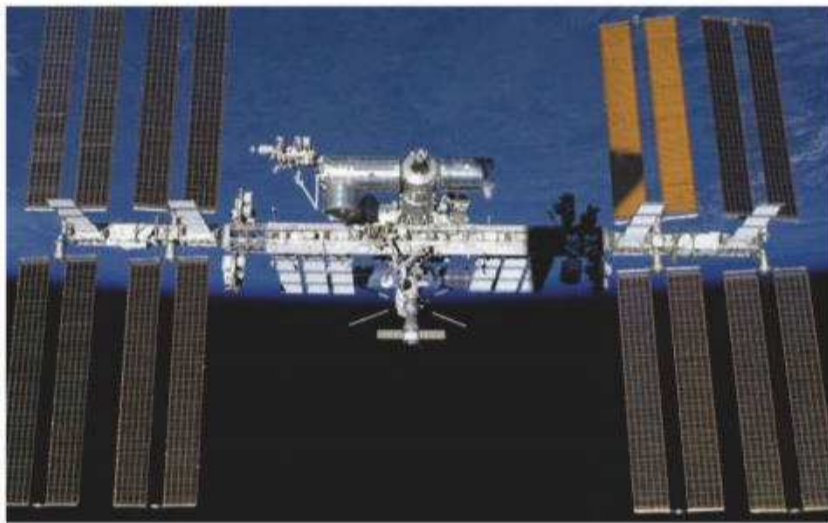
dioxide. Did they come from comets and asteroids, did they erupt from inside the Moon itself, or did they come from somewhere else entirely? "Answering this question could tell us about the origins of volatiles in the inner Solar System, and where the volatiles that enabled life on Earth came from," says Carpenter.

Other experiments have been mooted, like analysing the dust that drifts in deep space – including the interstellar dust from other solar systems – as well as studying ➤

SPACE STATIONS: WHAT COMES NEXT?

The future of the ISS is uncertain

The ISS is living on borrowed time. It has had several lifetime extensions before – first taking it beyond 2016, then to 2020, and finally through 2024. But all the signs are that NASA funding will dry up in 2025. NASA hopes that other countries and private companies will take over operating its modules. The trouble is, the ISS costs \$3-4bn a year to operate, so it's not clear how viable this will be. Rumoured alternatives include the ISS being broken up and individual modules sold off to private companies, or it being allowed to fall into Earth's atmosphere and burn up.



Private space stations

Some businesses have their sights set on building their own space stations from scratch. One front-runner, Bigelow Aerospace, has an expandable module, BEAM, that was latched onto the ISS in 2016 (above). The next step for Bigelow will be to launch larger inflatable modules. These units will expand out to 330m³ and it is anticipated that two will be ready for launch by 2021. Another company is Axiom Space. Its president and CEO is Michael Suffredini, a former ISS programme manager. Axiom also plans to link modules to the ISS before going it alone.

RIGHT:
Lighting up
the Utah
scenery while
testing the
boosters on
NASA's Space
Launch
System,
which will be
used to
launch
Gateway into
space



Book yourself a space station vacation

The next generation of space stations will be designed for tourists as well as astronauts. Houston-based Orion Span plans to offer stays aboard its luxury Aurora Station (below) from 2022. At \$9.5m, a trip to low Earth orbit won't come cheap. The experience will start with a three-month training plan, beginning with an app that it plans to release in 2019. Then it's off to Orion Span's facility in Texas, to learn about spacecraft systems and get some weightlessness practice. During the 12-day flight, visitors will be able to experience zero gravity, see the aurora borealis and grow food.



Russian rumours and Chinese certainty

While Russia is involved with the development of Gateway, there have been other reports too. One of these is that Russia plans to hive off some of its most recently added ISS modules in order to create a new station in low Earth orbit. But China has plans too. In 2011, it launched a space lab, Tiangong-1, which ended service in 2016. A successor, Tiangong-2 (above), was launched in September 2016. China sees both as testbeds for its main project: a large modular space station. A core cabin module is slated for launch in 2020, with the goal of having the station up and running by 2022.

the interaction between the solar wind and Earth's magnetic field. Whichever experiments are selected, they'll have to be operated remotely, as Gateway will be uncrewed most of the time.

A priority for Gateway will be to act as a test bed for the technology required for missions to Mars. But not everyone is convinced that it will achieve this. "None of the enabling technology you would need to get to Mars would be accomplished or tested using Gateway," says Terry Virts, a former NASA astronaut who spent 200 days aboard the ISS from 2014 to 2015. Virts says Gateway would not allow the development of a necessarily powerful propulsion system for getting to Mars, nor a nuclear energy system to power life support technology on the Martian surface. He says that the best way for astronauts to reach Mars would be aboard a high-speed craft, continually shuttling between Earth and the Red Planet, and that Gateway should be redesigned to do the same thing between the Earth and the Moon. "Let's practise getting to the Moon in a way we are going to get to Mars," he says.

Whether Gateway even happens at all is dependent on sufficient support and funding being provided by

politicians into the future. Key to this will be ESA's ministerial council meeting in late 2019 in Spain, where billions of euros of funding will be allocated to space projects. Developing the world's most powerful rocket, the Space Launch System, is also proving problematic – a recent report by NASA's own auditors criticised the rocket's spiralling cost and delays. But for now at least, Gateway has momentum – a momentum that could take astronauts further than they've ever been before.

And there's no denying that this would be a profound experience – particularly when the Earth and Moon are at their most distant. "The Moon would be about the size of a golf ball held at arm's length, and the Earth a little smaller even than that," says Clark. "So you wouldn't feel much attachment to either one. This would be a point of view shared by nobody else in the Solar System."

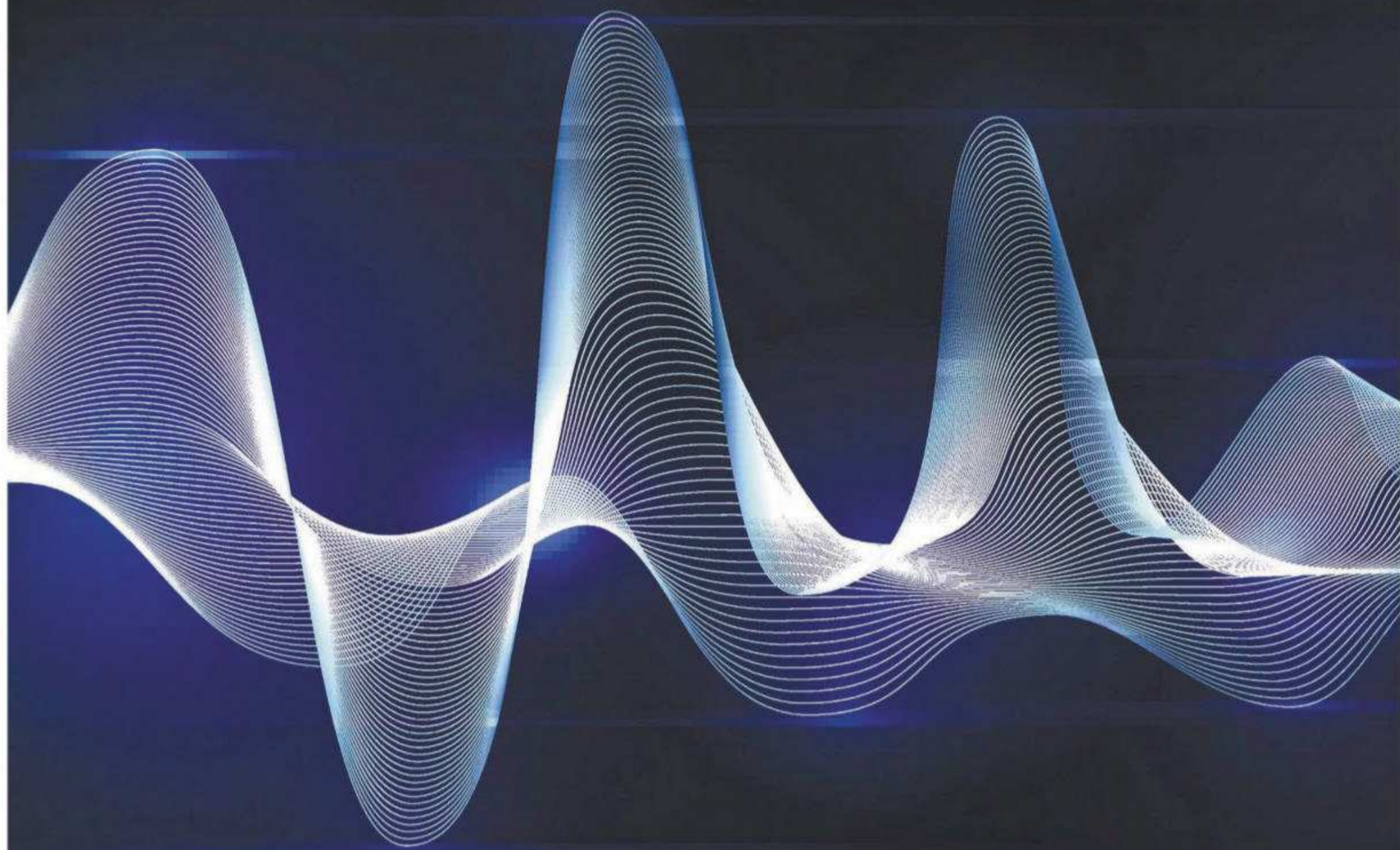
Andy Ridgway is a freelance science writer based in Bristol.

DISCOVER MORE

What did the ISS ever do for you? To find out, visit sciencefocus.com/space/what-the-iss-did-for-us/

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PROF ROBERT MATTHEWS
Physicist,
science writer

YOUR QUESTIONS ANSWERED

DECEMBER 2018

EDITED BY JAMES LLOYD

How do Venus flytraps know when to shut?

TOBY GRAHAM, SHREWSBURY

The inside surfaces of the Venus flytrap's two 'lobes' have six sensitive hairs – three on each one. The physical movement of these 'trigger hairs' is what springs the trap – but two hairs have to be touched within 20 seconds of each other for this to happen. This has evolved as a safety measure to stop the trap from going off when a raindrop hits it.

The movement of the trigger hairs causes the release of charged calcium particles (ions) from the cells at the base of each hair. When the concentration of calcium ions rises high enough, the trap closes in

less than a second by snapping from a convex to a concave shape, like an inverted contact lens popping the right way around. Initially, the trap closes quite loosely, with the long-fingered fringe at the edge of the lobes interlocking to form bars. This allows tiny insects that aren't worth the trouble of digesting to escape. But anything large enough to touch the trigger hairs another five times will cause the trap to close all the way – eventually forming a watertight seal so that enzymes can be released to digest the insect. **LV**

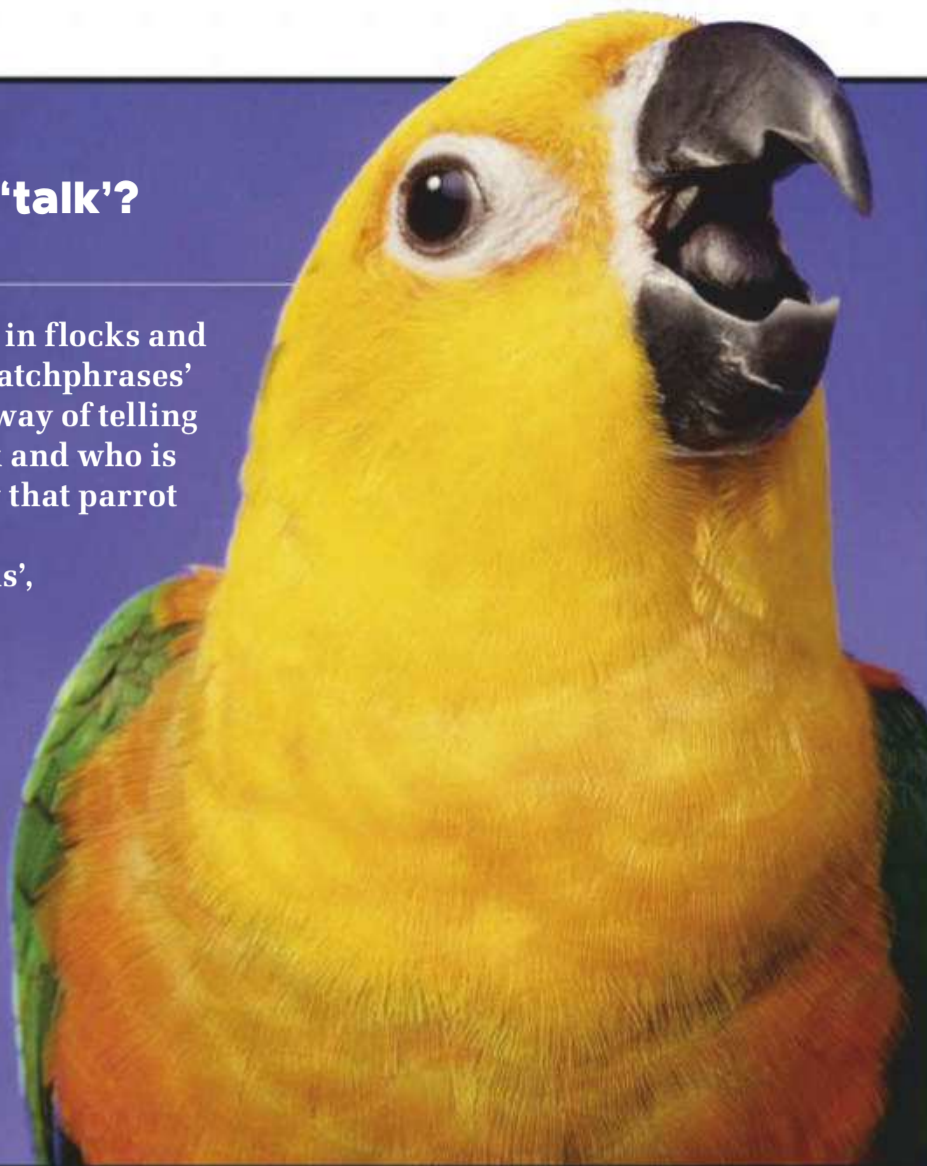


GETTY

How do parrots 'talk'?

HENRY WORRALL, LONDON

In the wild, parrots live in flocks and they learn to copy the 'catchphrases' of their own flock, as a way of telling who belongs to the flock and who is an outsider. Scans show that parrot brains have a different structure from songbirds', and this can help to explain why they're so good at vocal learning. In captivity, alone in a cage, the only vocalisations available to parrots are human speech, so they naturally learn to imitate this instead. **LV**



Why does driving make us drowsy?

JANET FITZSIMMONS, MILTON KEYNES

Nodding off at the wheel is a common experience – and a potentially deadly one. Globally it's estimated to play a part in 250,000 deaths each year. But while it obviously makes no sense to drive when already half-asleep, research suggests that just being in a moving car can trigger drowsiness in as little as 15 minutes. This July, a team at RMIT University, Australia, published research suggesting it's the vibrations we experience while driving that trigger sleepiness. Exactly how isn't clear; intriguingly, however, the frequency of vibration required is around seven cycles per second – similar to that of so-called theta wave activity in the brain, which is linked to falling asleep. Other studies have suggested that the hiss-like 'white noise' generated by the wheels also plays a role. **RM**

WHAT CONNECTS...

...MANNEQUINS AND NUCLEAR WARFARE?

1.



In 1953, the US Federal Civil Defense Administration (FCDA) built two houses in the Nevada desert. The families living there were actually mannequins donated by American department stores.

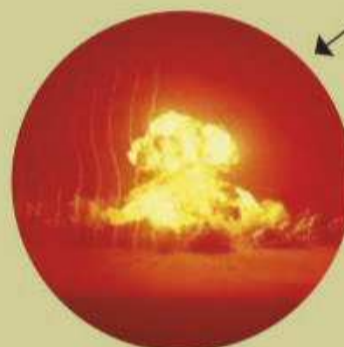
2.

This was part of 'Operation Doorstep' – a test to see what the effects of a nuclear strike would be on a typical suburban home. The houses were placed 1km and 2.5km from 'ground zero'.



3.

The 15-kiloton atomic bomb was detonated from the top of a 90m tower to replicate an air-burst explosion, similar to the bomb dropped on Hiroshima eight years earlier.



4.

Damage to the mannequins showed that any above-ground occupants in either house would have been killed. But surprisingly, those mannequins sheltering in the basements were protected from the initial blast.



If energy can't be created, where did it come from in the first place?

ELLIOTT FARQUHAR, VIA EMAIL



We're taught at school that energy can't be created, merely converted from one form to another. But at the birth of the Universe – that is, everything – the energy needed for the Big Bang must have come from somewhere. Many cosmologists think its origin lies in so-called quantum uncertainty, which is known to allow energy to emerge literally from nowhere. What isn't clear, however, is why this cosmic energy persisted long enough to drive the Big Bang. **RM**



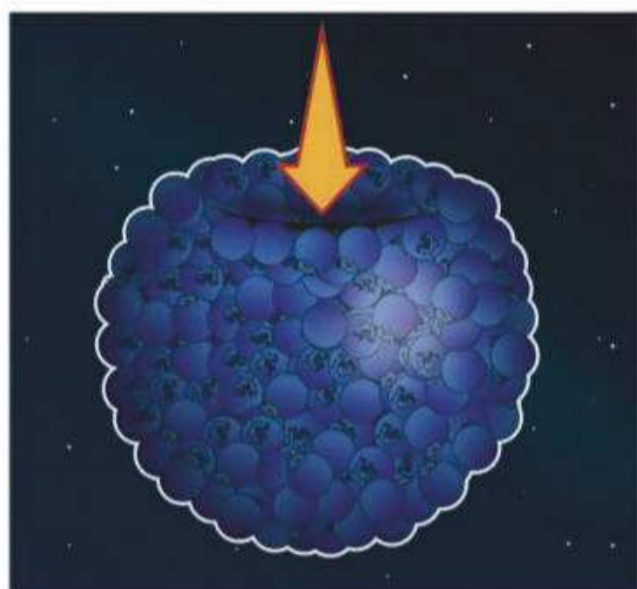
Why does rain smell so good?

CARL DENNIS, CUMBRIA

The fresh, earthy smell that we associate with rain, known as 'petrichor', comes from a variety of sources. During dry conditions, certain plants release oils, which then become airborne under the impact of rain. Falling raindrops also stir up the soil, propelling a musky-smelling chemical secreted by bacteria, called geosmin, into the air. Finally, lightning can split molecules in the atmosphere to form ozone (O_3), which has a chlorine-like tang. Some scientists speculate that the importance of rain to our survival has led us to evolve to enjoy its smell. **AFC**

THE THOUGHT EXPERIMENT

WHAT IF THE EARTH WAS MADE OF BLUEBERRIES?



1. COMPLETE COLLAPSE

This question was actually addressed in a paper earlier this year by Dr Anders Sandberg at Oxford University's Future of Humanity Institute. If the Earth were instantly replaced with an equivalent volume of closely packed blueberries, they would immediately begin to collapse under their own gravity. The outer 715km of the planet would plummet inwards towards the core.



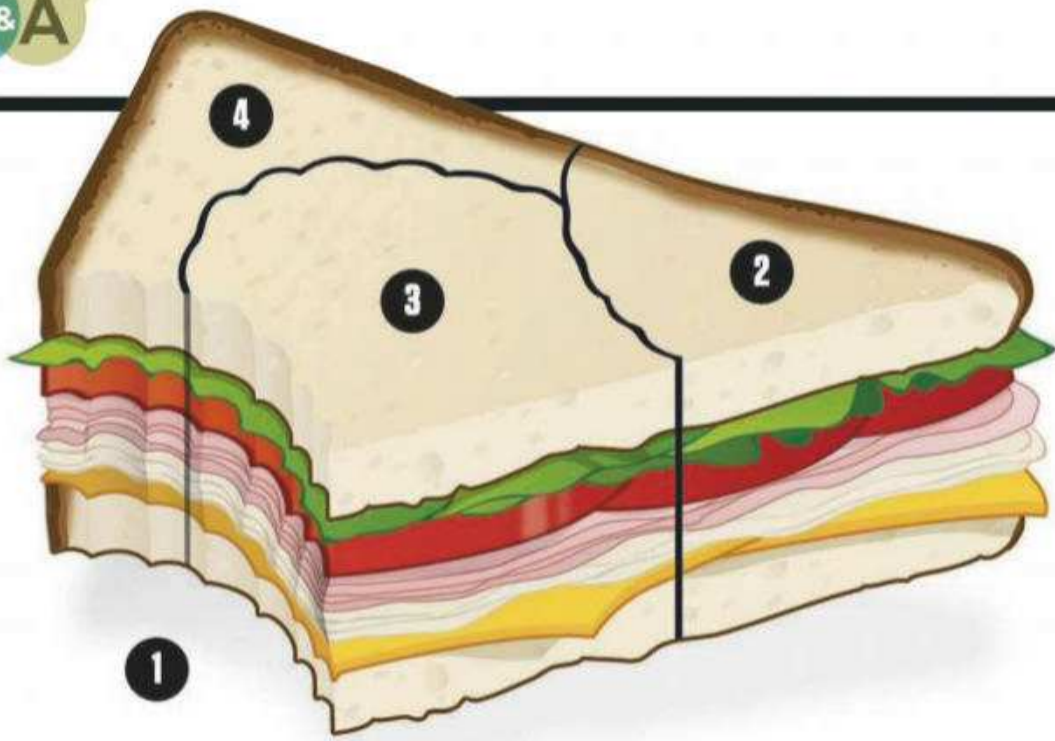
2. JUICE AND JAM

The collapsing berries would pulp themselves into juice and then boil into jam from the heat caused by friction and compressive heating as the planet implodes. Berry-quakes and jam-volcanoes would rage across the surface. The inner core would be a smoothie, compressed into a solid ball, with a temperature of several thousand degrees Celsius. The reduced size of the planet would cause it to rotate every 19 hours.



3. NO MOON!

Berries are less dense than rock, so the Earth would have less mass. This wouldn't leave it with enough gravity to hold on to the Moon, which would fly off into space. The air squeezed out from the spaces between the berries as the planet collapses amounts to more than 200 times the volume of Earth's atmosphere. The lower gravity means the atmosphere extends out six times further, causing satellites to re-enter and burn up.



Why do triangular sandwiches taste better than rectangular ones?

HATTIE TUCKER, POOLE

Several studies have confirmed this phenomenon. It seems that triangles give you more sandwich filling per bite. A triangular sandwich has two 45° corners that allow you to bite much further towards the middle on your first two bites, where there is more filling. This is followed up by a perfect, crustless third bite as you take the space left in the middle. Bite number four is, of course, mostly crust, but you can't have everything! **LV**



Why is television so addictive?

TOBY GRAHAM, SHREWSBURY

The idea that technologies, like TV, can be considered truly addictive in the same way as substances like nicotine and alcohol is controversial. Nonetheless, many of us spend huge amounts of time watching TV and – if we are honest – often more than we would like. Alongside the more obvious pulling power of cliffhangers and plot twists, TV's main attraction comes from its ability to serve many of our most basic psychological needs on tap, and with little cost. It allows us to alter our emotions, to learn, to find out what's happening in the world, and to enjoy long-running, so-called 'para-social', relationships with fictional characters, who can serve as substitute friends and relatives. And all this from the comfort of our sofas. **CJ**

Can trees predict the weather?

MICHAEL HIRST, VIA EMAIL

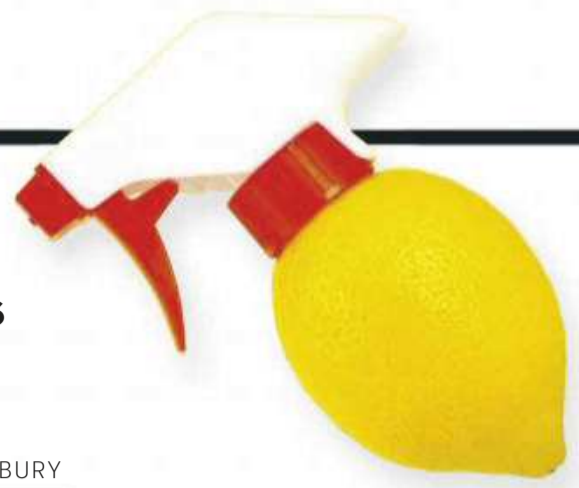
"Oak before ash, we'll have only a splash. Ash before oak, we're in for a soak." This saying claims that if oak trees come into leaf in spring before ash trees, then there will be less rain in the summer. Oak and ash trees do come into leaf at different times, because leaf growth in oaks is triggered by temperature, whereas ash trees use longer days as their signal. But there's no evidence that a warmer spring results in less rain that summer. Pine trees do close their cones in humid weather, though, which can indicate that rain is on its way. **LV**

GETTY X4 ILLUSTRATION: PETER SUCHESKI



Why do we associate citrus smells with being clean?

CATRIN AVERY, CANTERBURY



Lemons were used in the past for household cleaning. The citric acid in the juice dissolves limescale and was used to bring the shine back to copper pans. Lemon oil, from the peel, was used in wood polish. When commercial detergent and cream cleaners became widely available, lemon oil was an easy way to add a pleasant scent that was already associated with cleaning. Nowadays, so many cleaning products use lemon and lime scents that we have become conditioned to link the smell with cleaning. In 2005, Dutch researchers found that citrus smells can cause us to keep our kitchen cleaner, by subconsciously putting the idea of hygiene in our minds. **LV**

Galileo Galilei: the father of science?

Who was the first scientist?

KUZEY KILIÇ, TURKEY

The term 'scientist' is a relatively new invention, having been coined by British polymath William Whewell in 1833. Before then, those who tried to fathom the workings of nature were regarded as philosophers. As such, some regard the Ancient Greek thinker Aristotle to be the first scientist, because of his extensive study of natural phenomena. However, his belief that everything has a purpose, and his reliance on 'common sense', sometimes led him to erroneous conclusions – such as his idea that heavier objects drop faster than lighter ones. The 13th-Century scholar Roger Bacon has a better claim to being the first scientist, as he recognised the importance of experiment, and distrusted intuitions and apparently 'logical' deductions of the kind that misled Aristotle.

But for his pioneering use of experiment, observation and maths to understand nature, the Italian genius Galileo Galilei arguably best fits the description of 'first scientist'. **RM**

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WHO REALLY DISCOVERED?

THE HIGGS PARTICLE?

PETER
HIGGSFRANÇOIS
ENGLERTROBERT
BROUT

In 2012, scientists announced the detection of the Higgs particle, a crucial part of theories describing the basic forces of nature. Its existence had been proposed nearly 50 years earlier by the British theoretician Peter Higgs. But confirmation of his work sparked controversy about who should win the Nobel Prize, as Higgs was not the first to suggest the eponymous particle might exist.

A few weeks before Higgs' work appeared in October 1964, Belgian theorists François Englert and Robert Brout showed that some properties of atomic nuclei might be linked to a kind of force field. Theorists already knew that such force fields demand the existence of particles to transmit them, and Englert and Brout didn't go into details. Higgs went a bit further, giving a formula to describe the particle, but again made little of it.

It took a blunder by another theorist for Higgs to be widely credited with discovering the need for the particle. Steven Weinberg – who later won a Nobel for his own work on fundamental forces – accidentally credited Higgs as being the first to publish the theory. His authority then led others to talk simply of the Higgs particle. Fortunately, the Nobel Prize went to both Englert and Higgs, Brout having died in 2011. **RM**



Higgs and Englert (second and third from left) awarding the 2013 EPS High-Energy and Particle Physics Prize to its recipients for the discovery of the Higgs boson



Why is it rude to point?

ROB BANINO, BRISTOL

In many cultures, including ours, pointing at other people is considered rude because it's associated with blame allocation ('to point the finger at...'). Also, by pointing at someone, you automatically, and without their consent, make them an object of scrutiny. However, this taboo does not appear to be culturally universal. For instance, the anthropologist Olivier Le Guen notes that among the indigenous Yucatec Mayas in southern Mexico, it's not considered rude to point at others. **CJ**



Olympus Mons on Mars is the largest volcano in the Solar System

Do any other planets have plate tectonics?

CASSY SWAN, LEICESTERSHIRE

The idea that the Earth's fragmented crust drifts over the hot mantle beneath, often creating earthquakes and volcanoes, only gained widespread acceptance in the 1960s. Some planetary geologists believe that certain surface features on Mars, and the fact that it had active volcanoes during its earliest phase, indicate that the Red Planet may also have several crustal plates. Apart

from this possibility, which is as yet unconfirmed, Earth appears to be unique in the Solar System in having plate tectonics, driven by huge convective loops of hot rock. This may be because the Earth's interior has remained warm enough for the material to flow easily, and possibly because the Earth's crust is relatively thin, and so more easily cracked to form plates. **AGU**



WHAT IS THIS?

Bat bonanza

Thousands of eastern bent-wing bats huddle on the roof of a pedestrian tunnel in the mountains of Kōchi, Japan. For years, Japanese zoologists were puzzled where the bats went in the winter, as they could not find their roost. Finally, after much searching, around 4,000 of the animals were discovered in the tunnel.

In temperate regions, bats will hibernate when the weather gets colder. They lower their heart and breathing rates to save energy, and start emerging again when the weather warms up.

WHAT ARE THE LIMITS OF HUMAN ENDURANCE?

We teamed up with the folks behind BBC World Service's *CrowdScience* to answer your questions on one topic. You can tune into *CrowdScience* every Friday evening on BBC World Service, or catch up online at www.bbcworldservice.com/crowdscience

Is endurance in the mind or in the muscles?

When it comes to running, how far and how fast you can go is determined by a number of physical factors, including your VO_2 max (the volume of oxygen you can pump round your body) and your lactate threshold, which is the point at which your body produces more lactate than it can break down (a build-up of this chemical makes you run less efficiently). Some of this is genetic; some of it comes from training. But in recent years, sports scientists have also come to recognise the importance of mental strength. The longer you run, the more important a well-thought-out mental strategy is. Common strategies for coping with pain include motivational self-talk and distraction techniques to help block negative thoughts.

Will anyone ever run a two-hour marathon?

Thirty years ago, scientists calculated that the fastest possible marathon, in perfect conditions and with the perfect athlete, would be 1 hour 58 minutes. And we're getting close. This September, Kenyan long-distance runner Eliud Kipchoge (below) set a new world record of 2:01:39 at the Berlin Marathon – a race ideally suited to fast times because of its flat course, few corners, and typically good weather conditions. Sports physiologists think that the two-hour limit could be broken in the next few decades, as a bigger talent pool of runners, plus advances in training technology, create ever more ideal combinations of athlete and running conditions.



Kate Smyth was escorted from the track when she collapsed after running the marathon at the 2006 Commonwealth Games

Is endurance running bad for you?

Long-distance running stresses the body: recent research from the University of the Peloponnese in Greece found that post-race levels of inflammation in the blood of ultra-endurance runners (those who run races longer than a marathon) showed similar profiles to people with cancer or cirrhosis. However, over the next few days, the runners' levels returned to normal, suggesting that they have a remarkable ability to recover after an extreme workout. Good training is partly about building an awareness of your limits, so that you know when, for instance, you've crossed the line from 'good pain' into 'bad pain'.



Marnie Chesterton is the presenter of *What Are The Limits Of Human Endurance?* – an episode of *CrowdScience* that can be streamed at bbcworldservice.com/crowdscience



IN NUMBERS

17

The number of hours that the MASCOT lander survived on the asteroid Ryugu. Not bad, considering it was only meant to manage 16 hours!

5,000

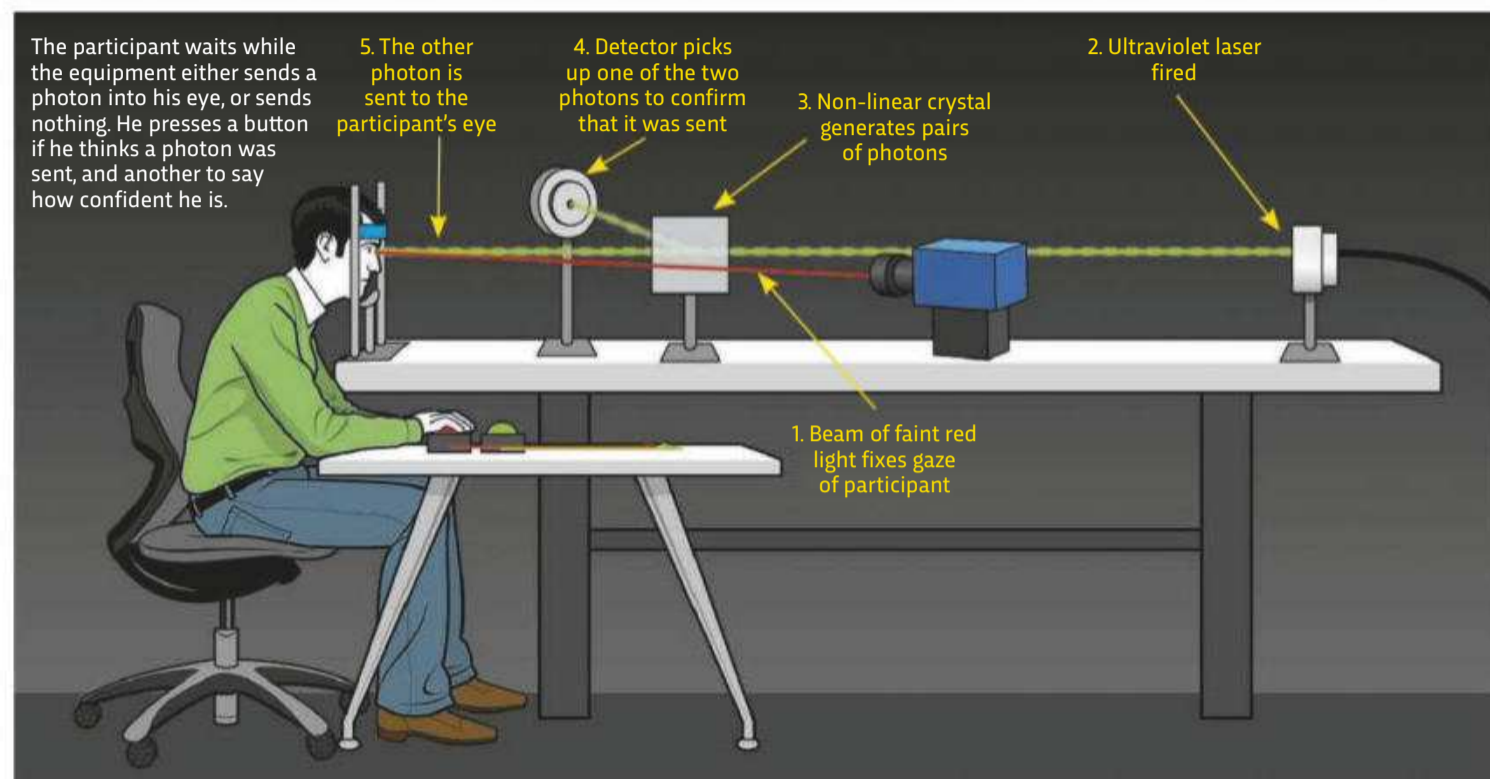
The number of faces, from family to celebrities, that most people can recall.

3,500

The age, in years, of nutmeg found in pots on an archaeological dig in Indonesia. It's the oldest known evidence of the spice as a food.

What's the fewest number of photons our eyes can detect?

ADAM KING, VIA TWITTER



The cells in our eyes responsible for vision respond to the packets of light energy known as photons. As early as the 1880s, experiments by the American physicist Samuel Langley found humans could detect bursts of light consisting of just a few thousand photons. But in 2016 a team led by Alipasha Vaziri at Rockefeller University in New York carried out

the ultimate test, using a special device capable of firing just one photon into the eye at a time. Three volunteers sat in pitch blackness for 40 minutes, and then had to say whenever they believed they'd noticed something from the device. The results suggested that while single photons can't be consciously seen, our eyes can still faintly sense their presence. **RM**

QUESTION OF THE MONTH

Can cats smile?

LISA MILNE (AGE 14), OXFORD

Cats have the muscular ability to make facial expressions that resemble smiling, but it's nothing to do with happiness! Certain odours, especially pheromone-rich ones like urine, can trigger the 'flehmen response', where cats draw scent particles to the roof of their mouth to be analysed by their extra sensory receptor, the Jacobson's organ. This behaviour is characterised by curled lips, a tilted head and squinting eyes – all of which can look like smiling. Cats may also bare their teeth in a kind of grin when feeling aggressive. Positive signs of a contented cat include purring, slow-blinking, paw-kneading, head-rubbing, meowing and tail-flicking – but never smiling! **cc**



WINNER!

Lisa wins a Lumie Bodyclock Glow 150 (£90, lumie.com). This alarm clock mimics the light and colour of a sunrise to gently wake you up in the morning. Features include: a choice of nine sleep/wake sounds, including white noise; fully adjustable bedroom lighting; a light-sensitive display; and tap-control snooze.



NEXT ISSUE:

Why do lions have manes?

Why is destruction so satisfying?

How old is the man on the Moon?

Email your questions to questions@sciencefocus.com or submit online at sciencefocus.com/qanda

OUT THERE

WHAT WE CAN'T WAIT TO DO THIS MONTH

DECEMBER 2018

EDITED BY HELEN GLENNY

01

SCIENCE MUSEUM, LONDON
FROM 19 OCTOBER 2018
SCIENCEMUSEUM.ORG.UK

BE WOWED BY PIONEERING SCIENTISTS

On 5 May 1930, aviator Amy Johnson left Croydon Airport in a secondhand Gipsy Moth biplane named Jason, bound for Australia. She arrived successfully, despite a sandstorm forcing her to land in the Iraqi desert, and a bumpy landing ripping a hole in the wing of her plane in Burma (modern-day Myanmar). She's one of 20 well-known scientists, inventors and explorers who have been drawn by iconic British illustrator Quentin Blake.

The illustrations are on display at London's Science Museum outside *Wonderlab: The Equinor Gallery*. This interactive gallery features slides to teach visitors about friction, and a chemistry bar will offer up hands-on experiments – why not pop in for a play?



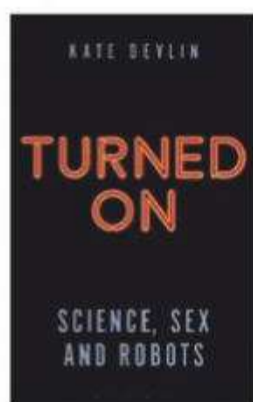


Pilot Amy Johnson (left) and polymath Jagadish Chandra Bose (above) are two pioneers that have been immortalised in illustration by Quentin Blake

02

**TURNED ON:
SCIENCE, SEX
AND ROBOTS**
KATE DEVLIN

OUT NOW
£16.99, BLOOMSBURY
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LEARN TO LOVE ROBOTS

Computer scientist KATE DEVLIN researches the ways in which sex, gender and sexuality could be incorporated into companion robots, and what those developments mean for society. She chats to HELEN GLENNY about her new book

What was your motivation for writing the book?

I was curious to see how we got to the point where we are actually starting to see the manufacture and delivery of the first sex robots. Where has this idea of the artificial partner come from, and what will it mean for society? Who benefits, and who might suffer?

How long have sex robots been around for?

Not long – the first commercially developed one is about to be shipped out to customers. But the idea has been around for millennia. The very first story was about a woman in Greece making a model in bronze of her husband who died in battle.

What do modern ones look like?

The only part of one that is robotic is its head. They have an animatronic head, but the body is completely stationary from the neck down. It's essentially a well-made, high-end doll with an AI personality. You can have conversations with it, and it can smile and look at you and turns its head.

What are the main benefits?

There are people out there who may be lonely, and robots could be a way of giving those people someone they can love and who will give the appearance of loving them back. For pleasure purposes, a robot can be someone they can have as a sexual partner.

And the drawbacks?

These robots have hyper-female figures and are usually white with blonde hair, which I think entrenches stereotypes and adds to concerns around body image. There are a lot of race issues in there as well. Also, what happens if people treat these robots badly? Does that spill into real life? What happens if someone makes a child-like version? What happens with data privacy and security? Anything that's connected to the internet is hackable. What happens if all your sexual secrets are stolen?

What about issues around consent?

We don't need to ask consent from a robot right now, because they aren't sentient, and may never be sentient, but perhaps we should be modelling consent as a reflection of what we want in society. In fact, one of the manufacturers is building consent into his robot, so you have to 'woo' her.

Where do you think this industry is headed?

Right now, I think this is an incredibly niche market; there aren't many being made. I think there's much more scope for creating intimate technologies that move away from the human form and into more abstract forms and immersive experiences.

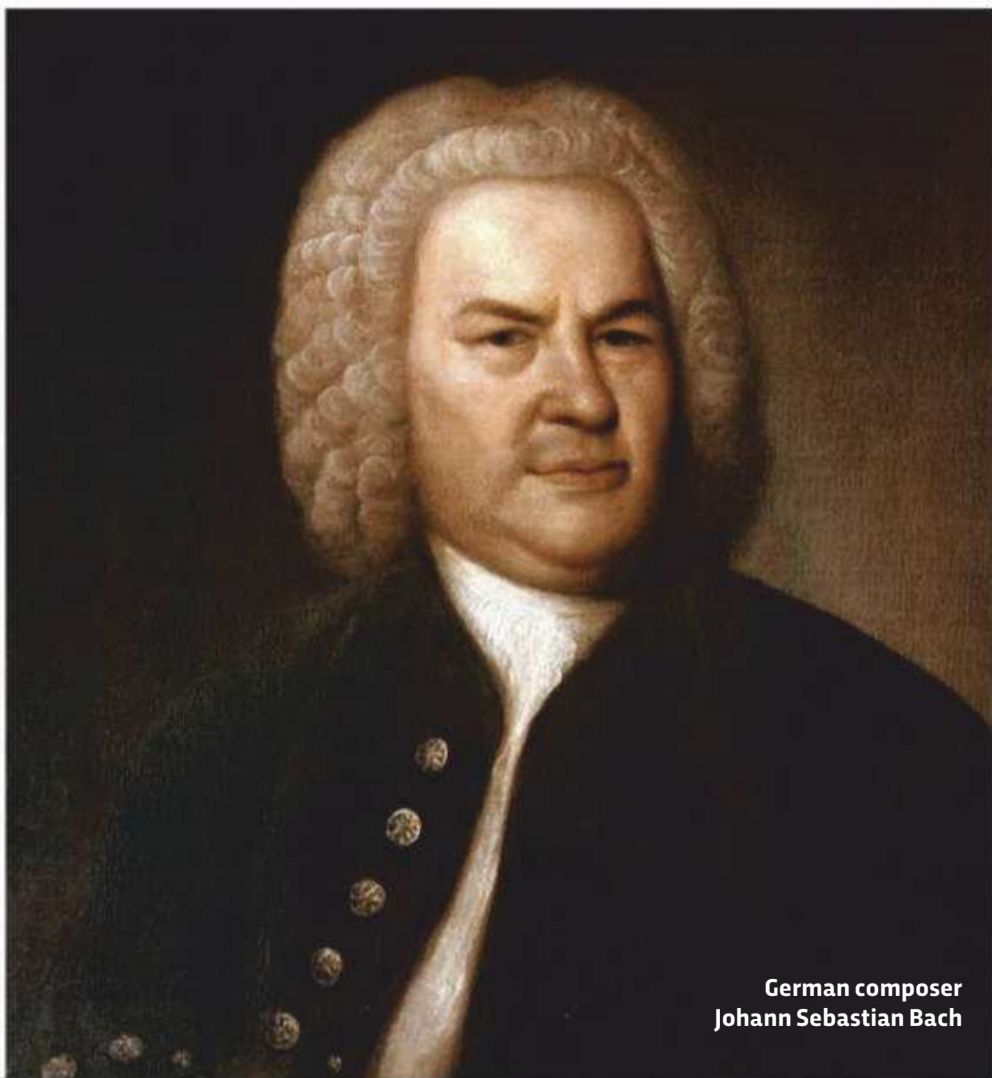
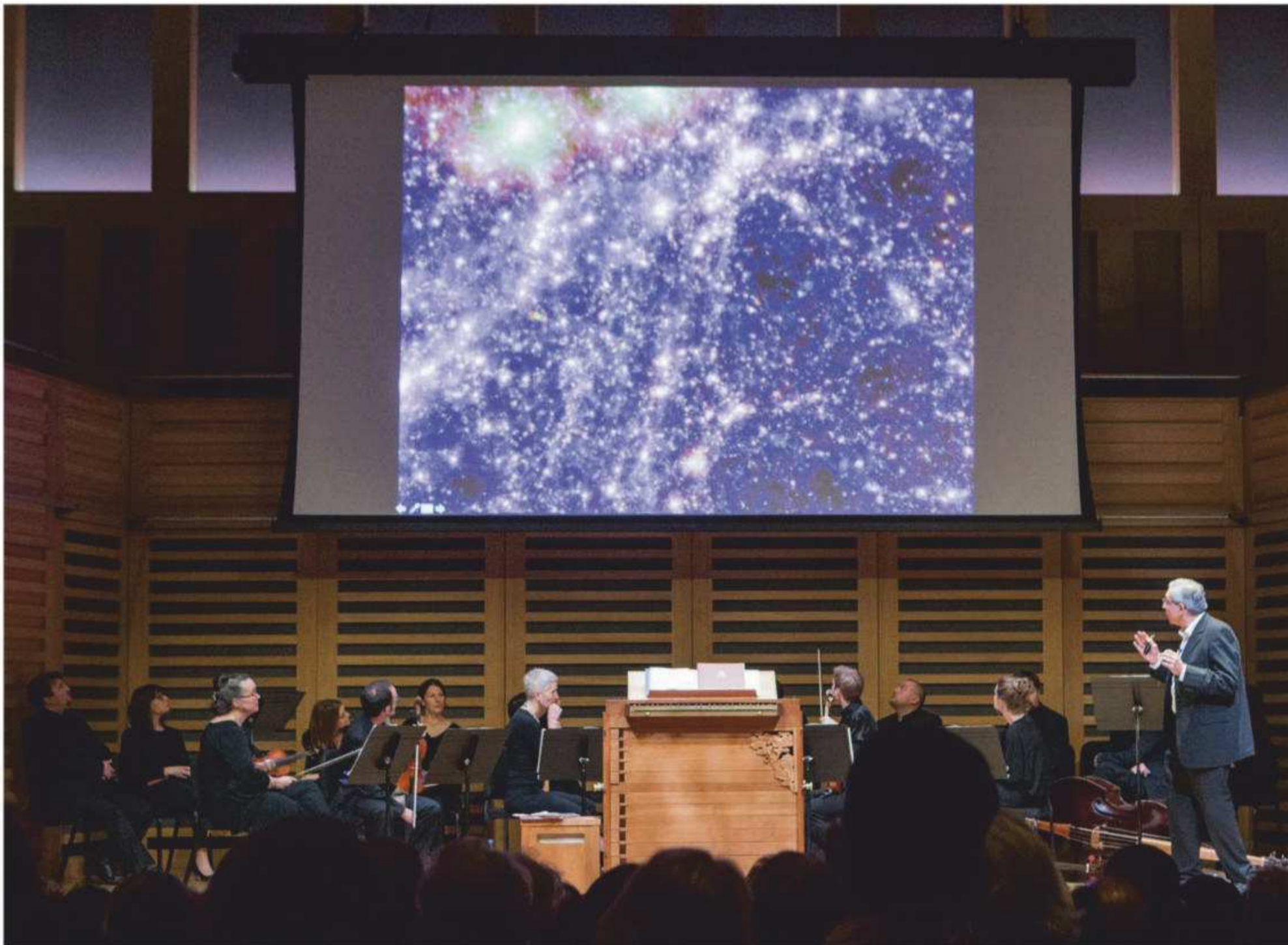


In 2016 and 2017 we ran a hackathon where people prototyped technology for intimacy that isn't based around the human form. We had people who made tentacle-like structures out of silicone, and these tentacles would squeeze a body part – you could put it on your body and it would hug you. We had someone else create a shawl that had sensors in it, so in virtual reality the sensors would trigger in response to your environment. Maybe that's the way this technology is headed. The headlines we see about sex robots tend to be doom-laden, about mass panic and morality. This isn't reflecting the reality, which is that they exist in such small numbers that they won't impact our everyday lives. That said, they're a fascinating way to raise questions about how we behave and form relationships.

FIND OUT MORE



Listen to our interview with Kate Devlin on the *Science Focus* podcast. Visit sciencefocus.com/sciencefocuspodcast



German composer
Johann Sebastian Bach

03

BACH, THE UNIVERSE & EVERYTHING

KINGS PLACE, LONDON
FROM 25 NOVEMBER 2018
KINGSPLACE.CO.UK/BTUAUE

Visitors to Kings
Place on Sunday
mornings can enjoy
Bach AND science.
What's not to like?

MARVEL TO MUSIC

How do you usually spend your Sunday mornings? Do you have a lazy lie-in? Or go for a stroll around the park? Starting from 25 November, you can immerse yourself in Bach's cantatas, and enjoy a talk from an expert in physics or astronomy at the same time. *Bach, The Universe & Everything* is a new monthly event by the Orchestra of the Age of Enlightenment and the Institute of Physics that offers the perfect opportunity to unravel the mysteries of the Universe. On 25 November, Prof Suzanne Aigrain will reveal how we can find exoplanets that might harbour human life. On concert days, the Institute of Physics will also be hosting interactive physics activities at the venue before and after the event.

04

INTIMACYSCIENCE GALLERY DUBLIN
UNTIL 24 FEBRUARY 2019
DUBLIN.SCIENCEGALLERY.COM

GET INTIMATE WITH SCIENCE

We like, retweet and favourite things on social media, giving feedback to our devices about how we're feeling. Now, an app called *Pplkpr* is attempting to do the same to our social lives. Through a smartwatch, the app monitors your physical and emotional reactions to the people you spend time with, then decides who should be auto-scheduled into your life, and who should be deleted.

It's part art project, part real app, and you can give it a whirl at *Intimacy*, an exhibition at the Science Gallery Dublin that explores how we relate to and connect with one another. You can also have a cuddle with a robotic companion cat, investigate how algorithmic logic might one day explain our intimate moments, and map the limits of your personal space.

Creepy or cute? The Kissenger device, which is on display at *Intimacy*, attaches to your phone and uses sensors to transmit your smooch to your partner



05

HOW TO CHANGE THE WORLDROYAL GEOGRAPHICAL SOCIETY
6 DECEMBER 2018
HOWTOACADEMY.COM

CHANGE THE WORLD

Get Jane Goodall's tips on making the world a better place for people and animals, or learn about the future of humanity from Astronomer Royal Martin Rees at *How To Change The World*, an all-day conference from the Royal Geographical Society. With 17 influential speakers tackling topics from conquering ageing to global food waste, this is an eye-opening event that'll give you insight into the world's future, both near and distant.

Jane Goodall (left) is one of the speakers at the *How To Change The World* event

GETTY

Let us know what you think for a chance to win a £250 Amazon Voucher!

Would you like to have your say in the development of BBC Focus Magazine?

Every year, we carry out research on behalf of BBC Studios that invites readers to share their views about this magazine and other BBC Studios titles.

This essential research is used by BBC Studios and the editors to shape future content and strategy for the magazines. We would really appreciate your time to help us with this research.

To take part in the research and be entered into a prize draw to win a £250 Amazon Voucher, please visit:

bbcstudios.com/survey

The survey will take less than 10 minutes and is being conducted according to Market Research Society guidelines. All of your responses are completely confidential.

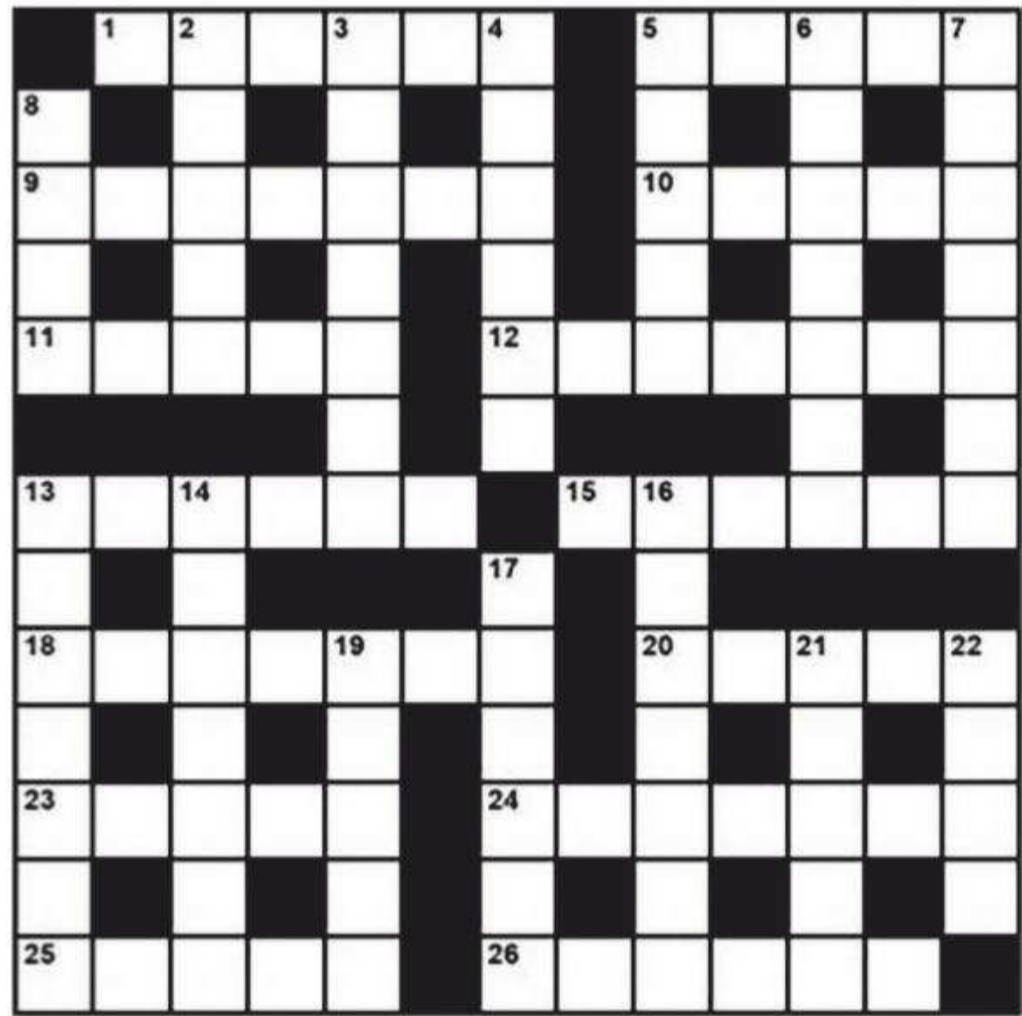
Terms and conditions: The prize is one £250 Amazon Voucher. One winner will be drawn at random after the closing date at 23.59 on 31st December 2018. Open to all residents of the UK and the Channel Islands aged 18 years or over except employees of BBC Studios or the BBC, their contractors, members of their families and anyone connected with this prize draw. Only one entry permitted per person. There is no cash alternative and the prize is not transferable. No purchase necessary. The prize draw is subject to the laws of England and Wales. Promoter: BBC Studios Limited, Television Centre, 101 Wood Lane, London W12 7FA. Your data will be used for the purposes of administration of this prize draw and in accordance with BBC Studios's Privacy Policy (www.bbcworldwide.com/home/privacy/). Where consent has been provided, BBC Studios may send email marketing messages from which you may unsubscribe at any time.



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GIVE YOUR BRAIN A WORKOUT



ACROSS

- 1 Before midsummer, mother gets a novice a cat, say (6)
- 5 Every character joins the heartless Catholic empire (5)
- 9 Ring with information on fluorine, for example (7)
- 10 A French veto about island – that’s negative (5)
- 11 Quiet time after weep in vault (5)
- 12 Crack bad habit, putting credit note first (7)
- 13 Study distributed by NATO (6)
- 15 Heard officer was a nut (6)
- 18 Managed to get one to show respect for weather feature (7)
- 20 Simpleton returns to par-boil stew (5)
- 23 Attorney and Scot sent back watery spirit (5)
- 24 He would send card about cheese (7)
- 25 Turn and dance (5)
- 26 In the morning, shot for theatrical behaviour (2-4)

DOWN

- 2 Friend swallows oxygen mixture (5)
- 3 Game not played a great deal (7)
- 4 Sculpting clay outside – a French madness (6)
- 5 A portal of stone (5)
- 6 Teaching gut feeling, but not at home (7)
- 7 Line dance with energy by large set (7)
- 8 Elegant bird with no knowledge (4)
- 13 Brat involved with single peer (7)
- 14 It is wrong to take back liberal capital (7)
- 16 Encourage chief to be a boffin (7)
- 17 Terrible whack to a currency (6)
- 19 Debit arranged for bathroom furniture (5)
- 21 Dime wasted on a radio, is one of them (5)
- 22 Dog really captured a monster (4)

ANSWERS

For the answers, visit bit.ly/BBCFocusCW
Please be aware the website address is case-sensitive.

NEXT MONTH IN

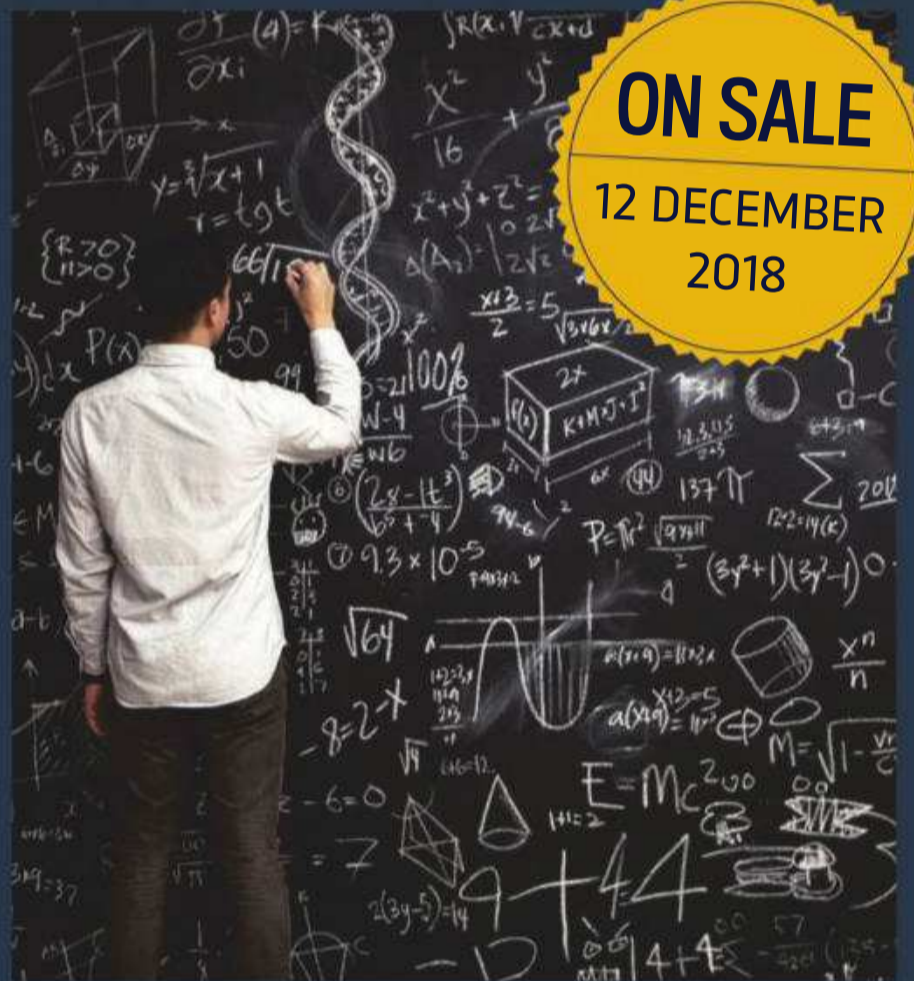
FOCUS

The instant genius issue

GAME-CHANGING IDEAS YOU
NEED TO GET YOUR HEAD AROUND

ON SALE

12 DECEMBER
2018

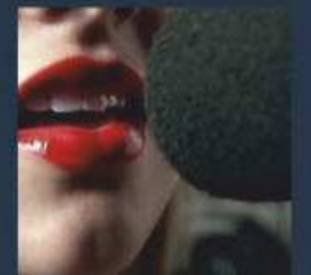


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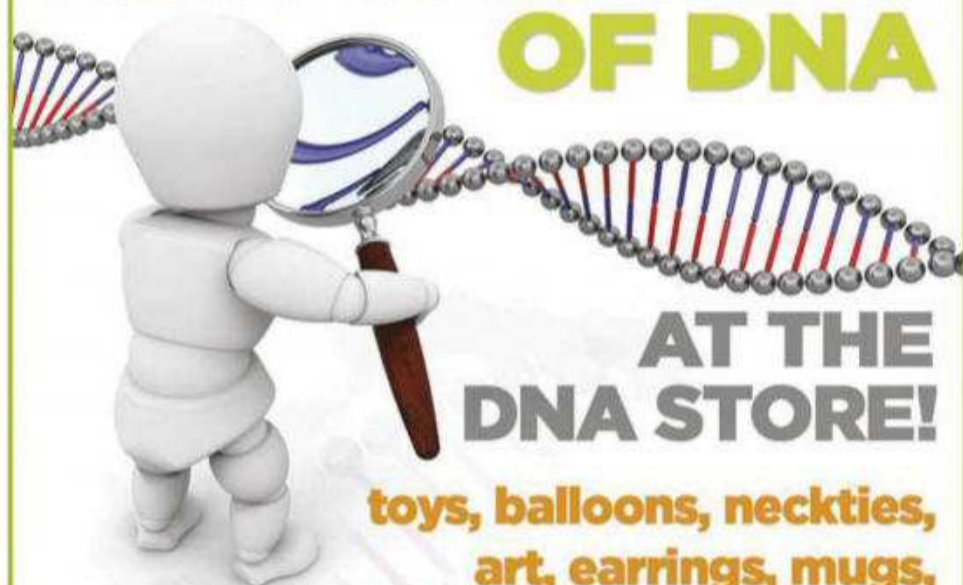
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MY LIFE SCIENTIFIC

Dr Sue Black

This month, computer scientist **Dr Sue Black** talks to **Helen Pilcher** about the transformative power of technology and saving Bletchley Park

In 2016, Sue was awarded an OBE for services to technology in the Queen's New Year's Honours list.

You describe yourself as a 'technology evangelist'. Why?

Because technology changed my life. My mum died when I was 12 and I left school at 16. When I was 25, I had a broken marriage and was living in a women's refuge. Then, when my kids went to school, I did a computing degree. My supervisor asked me if I wanted to do a PhD. I said I'd love to, but didn't tell him I had no idea what one was!

And then?

Technology took me from living on benefits on a council estate, to the

career that I have today as a keynote speaker and computer scientist. It worries me that people are missing out on opportunities because they are scared of technology. We can solve the world's biggest problems by empowering disadvantaged people with technological skills.

How do you get the message out?

I set up an organisation called #techmums that helps women learn about social media, online safety and coding. We teach online and in disadvantaged areas, and recently ran #techmumsTV in collaboration with Facebook. More than 300,000

people watched it and we had mums telling us it helped give them the confidence to seek jobs involving technology.

Should parents be concerned about social media?

I worry about parents banning kids from social media because they might use it anyway, have something go wrong and then have no one to talk to. People worry about social media with good reason, but it can also be useful. It helped us save Bletchley Park.

How?

By raising awareness. I initially thought Bletchley Park was maybe 50 old men who wore tweed and did *The Times* crossword and the odd bit of codebreaking. Then I learned that 10,000 people worked there and more than half were women. Their efforts shortened WWII by two years and saved 22 million lives. When I heard Bletchley could close, I knew I had to do something, so I turned to Twitter. One day, Stephen Fry retweeted me, and for a short time I became the most retweeted person in the world! I don't think we would have saved Bletchley Park without Twitter.

Any career disasters you'll admit to?

My laptop died when I was doing my PhD and I lost loads of work. I didn't admit it to anyone because I was horrified. It took me three months to accept what happened, then another three to redo it. It taught me to back up my research.

Who would play you in a film of your life?

Funny you should ask that. I was recently contacted by a film director who wants to do just that! I'd have Emma Watson for the young me and Angelina Jolie for the older me. They're both very #GirlPower. 🍌

Dr Sue Black is a computer scientist at University College London, and author of *Saving Bletchley Park* (£16.99, Unbound).

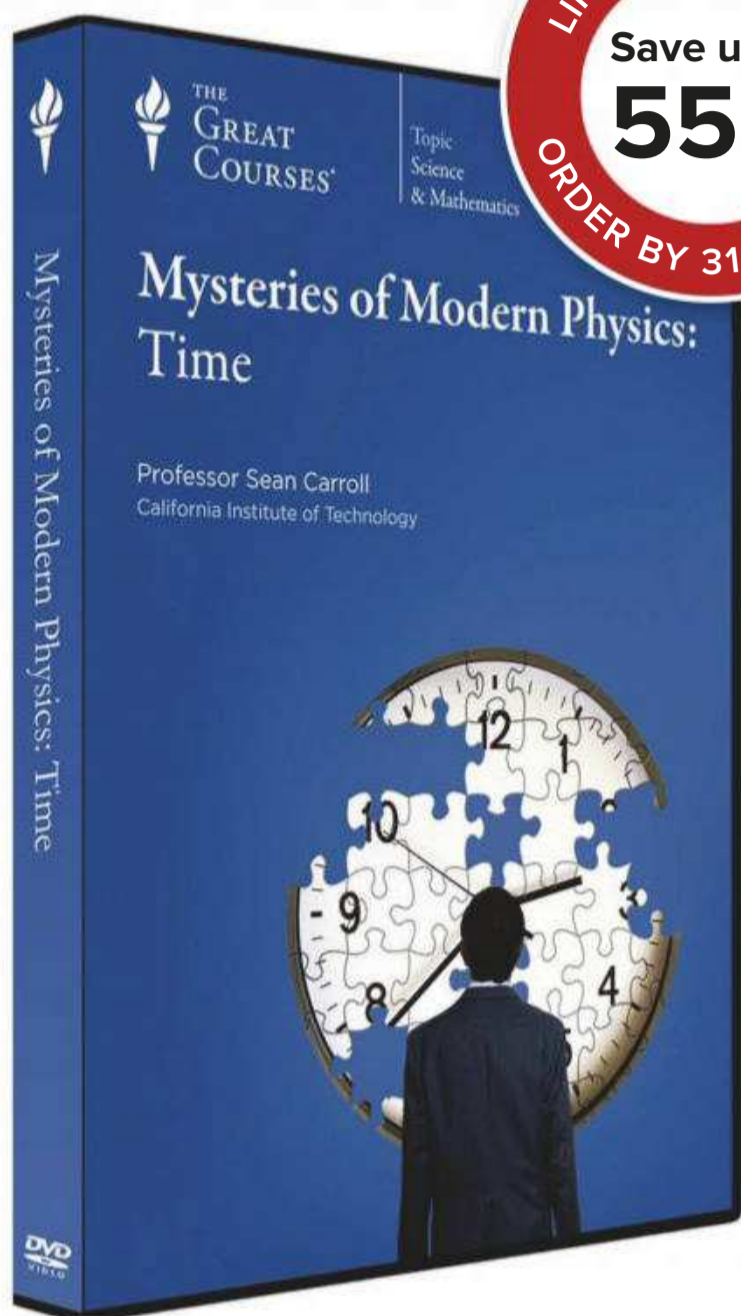
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NEXT ISSUE: ZOE LAUGHLIN

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Investigate Clues to the Origin of Time

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